PROCEEDINGS
OF THE . .
INSTITUTE OF
BRITISH FOUNDRYMEN.

VOLUME XXI. 1927-1928.

Containing the Report of the Twenty-fifth Annual Conference, held in Leicester, June 12th, 13th, 14th and 15th, 1928; and also Papers and Discussions presented at Branch Meetings held during the Session 1927-1928.

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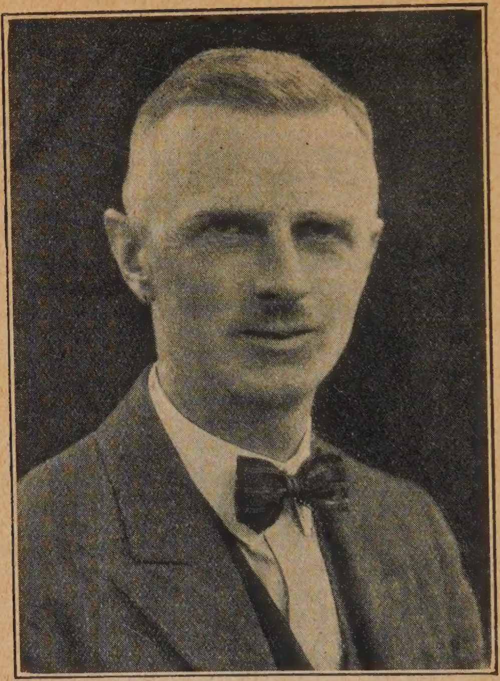

MR. S. H. RUSSELL,

President, 1928-29.

Mr. Russell is a partner in the well-known firm of Messrs. S. Russell & Sons, ironfounders and engineers, of Leicester. This concern was established in 1864 by Mr. Russell's grandfather. He was educated at Wyggeston Grammar School, Leicester, and Birmingham University. He joined the Institute of British Foundrymen in 1908, and was honorary secretary for the Leicester Convention in 1914. It was largely through his efforts that the East Midlands Branch was formed. In 1923 he presided over this branch. He became actively associated with the British Cast Iron Research Association on its formation, and served on its Council. In 1926 Mr. Russell, when vice-president, together with Mr. John Cameron (a past-president), officially represented the Institute at the International Foundrymen's Convention held in Detroit.

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THE INSTITUTE OF BRITISH FOUNDRYMEN.

OFFICERS 1928—1929.

PRESIDENT:

S. H. Russell, Bath Lane, Leicester.

VICE-PRESIDENTS:

Wesley Lambert, J. Stone & Company, Limited, Deptford, London, S.E.14.
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PAST-PRESIDENTS:

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C. Jones. (Deceased 1923.) 1912.
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W. Mayer. (Deceased 1923.) 1915.
J. Ellis, 51, Riddings Lane, Wednesbury. 1916-1917.
T. H. Firth. (Deceased 1925.) 1918.
John Little, M.I.Mech.E., 20, St. Ann's Square, Manchester. 1919.
Matt. Riddell, 35, Aytoun Road, Pollokshields, Glasgow. 1920.
Oliver Stubbs, M.I.Mech.E., Openshaw, Manchester. 1921.
H. L. Reason, M.I.Mech.E., M.I.M. 1922.
Oliver Stubbs, M.I.Mech.E., Openshaw, Manchester. 1923.
R. O. Patterson, Pioneer Works, Blaydon-on-Tyne. 1924.
J. Cameron, J.P., Cameron & Robertson, Limited, Kirkintilloch. 1925.
V. C. Faulkner, M.I.M., 49, Wellington Street, Strand, London, W.C.2. 1926.
J. T. Goodwin, M.B.E., M.I.Mech.E., The Red House, Old Whittington, Chesterfield. 1927.

HON. TREASURER:

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(Districts represented are shown in brackets.)

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†A. Campion, 3, Strathview Gardens, Bearsden, by Glasgow.

*H. C. Dews, Dewrance & Co., 165, Gt. Dover Street, London, S.E.1. (London.)

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*F. C. Edwards, 32, Queen's Head Road, Handsworth, Birmingham. (Birmingham.)

†W. T. Evans, Mount Pleasant, Sunny Hill, Normanton, Derby.

†A. Firth, 50, Clarendon Road, Fulwood, Sheffield.

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*W. Jolley, Breeze Hill, Urmston Lane, Stretford, Manchester. (Lancs.)

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*E. H. Tyson, 269, Gillatt Road, Edgbaston, Birmingham. (Birmingham.)

*B. H. Vaughan, 25, Holmes Street, Derby. (East Midlands.)

†H. Winterton, "Moorlands," Milngavie, Dunbartonshire.

*D. H. Wood, "Kingswood," Park Road, Moseley, Birmingham. (Birmingham.)

*A. S. Worcester, Toria House, 162, Victoria Street, Lockwood, Huddersfield. (W.R. of Yorks.)

J. G. Pearce, B.Sc., M.I.E.E., British Cast Iron Research Association, 24, St. Paul's Square, Birmingham.

* Branch Delegates. † Elected at Annual Conference.

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(Ex-officio Members of General Council.)

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F. K. Neath, B.Sc., 24, St. Paul's Square, Birmingham.

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H. Bunting, 82, Otter Street, Derby.

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N. D. Ridsdale, 3, Wilson Street, Middlesbrough.

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F. Sanderson, 15, Handyside Arcade, Newcastle-on-Tyne.

SCOTTISH.

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J. Bell, 60, St. Enoch Square, Glasgow.

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A. M. Cleverley, B.Sc., 24, York Street, Falkirk.

SCOTTISH—PAISLEY SECTION.

G. Mackay, 103, Glasgow Road, Paisley.
J. Y. Anderson, 35, Alice Street, Paisley.

SHEFFIELD.

J. T. Goodwin, M.B.E., M.I.MechE., Sheepbridge Coal & Iron Co., Ltd., Chesterfield.
T. R. Walker, B.A., 26, Castlewood Road, Fulwood, Sheffield.

WEST RIDING OF YORKS.

W. G. Thornton, 1081, Grangefield Avenue, Thornbury, Bradford.
S. W. Wise, 110, Pullan Avenue, Eccleshill, Bradford.

WALES AND MONMOUTH.

R. G. Williams, "Rossmore," Calcot Road, Barry.
J. J. McClelland, M.I.Mech.E., "Druslyn," 81, Bishop's Road, Whitchurch, Glam.

AWARDS 1927—1928.

THE "OLIVER STUBBS" GOLD MEDAL

1928 Award to J. W. DONALDSON, D.Sc., A.I.C., "for papers presented to this Institute embodying his researches into the Properties of Cast Iron."

DIPLOMAS OF THE INSTITUTE

were awarded as follows :—

Mr. A. J. BECK, for his Paper on "Some Methods of Production in a Modern Malleable Iron Foundry," given before the East Midlands Branch.

Mr. F. HUDSON, for his Paper on "Scottish Moulding Sands," given before the Scottish Branch.

Mr. W. H. POOLE, for his Paper on "Cupola Practice," given before the Newcastle Branch.

Mr. N. D. RIDSDALE, for his Paper on "Practical Moulding Sand Control," given before the Middlesbrough Branch.

Mr. P. A. RUSSELL, B.Sc., for his Paper on "Shrinkage Holes in Small Grey Iron Castings," given before the East Midlands Branch.

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The Institute of British Foundrymen

ANNUAL CONFERENCE HELD IN LEICESTER.

June 12, 13, 14 and 15, 1928.

The twenty-fifth annual meeting and conference of the Institute of British Foundrymen was held in Leicester from Tuesday, June 12, to Friday, June 15, under the presidency of Mr. S. H. Russell.

There were present more than 300 members and visitors. The programme which had been arranged for their instruction and entertainment included the reading and discussion of Papers, visits to works and social functions. As usual, a special ladies' programme was provided.

TUESDAY, JUNE 12.

On Tuesday evening the members and visitors enjoyed the hospitality of the Mayor and Mayoress of Leicester (Alderman and Mrs. J. Thomas) at the De Montfort Hall, Leicester, taking the opportunity of recalling old friendships and making fresh ones. Some excellent dancing and music were special attractions in a most enjoyable evening, which was cordially appreciated by all present.

WEDNESDAY, JUNE 13.

The Conference was held at the Y.M.C.A. Hall, London Road, and the members gathered there early on Wednesday morning, when the Mayor

(Alderman J. Thomas) accorded the delegates a civic welcome.

Civic Welcome.

The Mayor, in welcoming the delegates, said that it gave him the greatest possible pleasure to extend to them a very warm and hearty welcome to the ancient city of Leicester. He certainly hoped that their visit would be an enjoyable one, and that their deliberations would not only be to their satisfaction but interesting to them all. They would be considering subjects of a very technical character. The main object of such conferences, especially in an Association like theirs, was that they should get into touch with members from different parts of the country, and by means of these gatherings they would be able to compare notes with each other, and so come to conclusions with regard to certain methods in their special industry which must ultimately result in benefit to industry generally. (Applause.) From his knowledge of it, he considered their industry was one of the most important in the country. Without the ironfounders he did not know where the engineers would be. (Applause.) It would be impossible for the engineering business to be carried on as it was carried on without the assistance of the ironfounders. Arrangements had been made with the Tramways Committee of the city whereby all the delegates and their wives and lady friends might travel free on the tramcars and 'buses throughout the city. (Applause.) Leicester was a city 2,000 years ago, and had played a most important part in the making of the history of England. Amongst other ancient buildings there was Leicester Castle, which was the Mother of Parliaments, because, in 1201, the then Earl of Leicester convened a meeting of the Barons with a view to checking the excesses of King John, which resulted in the signing of Magna Carta at Runnymede 14 years afterwards. That was the reason that Leicester Castle was known as the birthplace of Magna Carta, and also the birthplace of Parliament. In 1265, it was Simon de Montfort, Earl of Leicester, who gave to the people of England representative government, when he asked the counties and towns to send representatives to Parliament. That was the original formation of Parliament in England. In the year 1300, there were two meetings of Parliament in Leicester, and, in 1414, there was another meeting of the English Parliament in Leicester, the reason assigned being that the air of Westminster was unsalubrious. (Hear, hear.) Speaking of Leicester as an industrial city, the Mayor said that Leicester was the busiest, the most prosperous, and the cleanest city in England. (Applause.) Unemployment was very rife in England generally, as they all knew, but he was very happy to be in a position to say that Leicester had a lower percentage of unemployment than any other city or town in England. (Cheers.) Unlike some other other towns, especially the northern towns, Leicester was not dependent on one or two industries, but there were a large number of industries available to afford employment to the people. When a town was dependent upon one or two industries, and those were industries as bad as the iron and steel and shipbuilding industries had been, every person in every household dependent on those industries suffered; but in Leicester there were so many industries, with many members of families engaged in them, that if one or two industries were in a bad way, there was still something coming into the family from those employed in the others. Socially, he always described Leicester as the hub and the queen of the Midland Counties. He did not think they would find another industrial city with a population round about a quarter of a million more like a garden city than Leicester. (Hear, hear.) They would find that Leicester enjoyed practically a real freedom from smoke; they could enjoy a clear, crystal sky. For an industrial centre they were very proud of that. (Applause.) Their working classes were well-dressed, well-shod, and well-conducted. They had some of the finest public parks in the country. Their freedom from crime was really wonderful. They might think that he was painting a very pretty picture of Leicester, but they were proud of Leicester, and he wanted them to go away not only with a good opinion of Leicester, but with an exalted opinion. He would only repeat, in conclusion, that it was a great pleasure to him to be there to extend to them the warmest and heartiest welcome possible.

Vote of Thanks to Mayor.

Mr. J. T. Goodwin, M.B.E., M.I.Mech.E. (the retiring President), who occupied the chair during the early part of the proceedings, in responding on behalf of the Conference, said that when one considered the antiquity of Leicester one realised that there had been handed down in that city the *esprit de corps* which had carried the Corporation and its officials through troublous times, with the result that Leicester was one of the finest cities in England. They were indeed proud that the Mayor had welcomed them at their 25th Conference. Those who had inaugurated their Institute had had great forethought and foresight as to the future requirements of their particular branch of industry. They were not like unto the words of poor Cardinal Wolsey when he came to Leicester and wrote to the Abbot: "I have come to lay my weary bones with you"; but they were alive, and very much alive. (Hear, hear.) In the history of their Institution they had had many world-renowned men associated with them, and they revered their memory. Unfortunately, one of the strongest stalwarts of the Association (Mr. Oliver Stubbs) was away owing to a serious illness; otherwise, he was glad that many of their old members had stayed with them, including some of the original promoters of the Institute. They, together with others, had done good work, and had laid a strong foundation stone upon which they were building up an institution of which the country would be proud. (Applause.)

Mr. Wesley Lambert, F.I.C. (of London), in seconding the motion, in a few well-chosen words, pointed out that though there were something like 62 elementary metals in all, none of those metals was of any use in industry until it was foundered, so that the foundryman, apart from the engineer, did duty for almost every industry. He did not think that was generally recognised, but the time would come when the foundryman would come into his own, and the foundry industry would be recognised as one of the most prominent of basic industries. He had very great pleasure in seconding the vote of thanks to the Mayor for coming that morning, and for his kindness to them on the previous hearing. (Applause.)

The vote of thanks was carried with acclamation.

The Mayor, in responding, thanked them for the warmth and cordiality with which they had received the vote, and added that that day was one of the days which would live in his memory for many years to come.

Annual General Meeting.

The business of the annual general meeting of the Institute was then proceeded with. The minutes of the last annual general meeting were taken as read, confirmed and signed.

The Secretary (Mr. T. Makemson) said messages of regret for non-attendance had been received from the following gentlemen :—M. Leon Thomas, President of the French Foundry Technical Association; M. Ramas, Hon. President of the same Association; M. Lamoureux, Vice-President of the Belgian Foundrymen's Association; Dr. Werner, President of the International Committee of Foundry Technical Associations; and Dr. Geilenkirchen, Director of the German Foundry Owners' Association. Messages of regret for non-attendance from their own members had been received from the following:—Messrs. Patterson, Little, R. W. Stubbs, Bayley, Christie, Wise, Sanderson, Roberts, Hay, Dawe, Starr, Bagshawe and Sommerfield.

Mr. Goodwin remarked that they deeply regretted the absence of their own members, and were greatly appreciative of the kind letters and telegrams they had received from kindred Associations. He had had handed to him a cablegram from Cleveland from the Association in America saying:—" Officers, directors, members, take pleasure in extending cordial best wishes for successful Convention. Estep, Chairman, Committee International Relations." He knew they would wish him to reciprocate those good wishes, and he would do so at the very first opportunity. (Applause.) A second telegram read:—" President, Institute British Foundrymen, Association Hall, Leicester. Best wishes for successful Convention." That had been sent from Lowestoft by Mr. W. G. Hollinworth. (Applause.)

He thought he would be voicing their thoughts when he said they ought not to forget one of their absent friends whose serious illness had prevented him from being with them; he referred to Mr. Oliver Stubbs. Though their old friend was very ill, he was delighted to report that on Sunday last there had been a decided change for the better. Mr. Stubbs and his family would have their deepest sympathy during that extremely trying time, and he would send on their behalf a message condoling with him on his illness and congratulating him on the slight recovery that he had had. (Applause.)

Annual Report of the General Council for the Year 1927-1928.—It was agreed that the Report of the Council be taken as read.

Annual Report of the General Council for the Year 1927-28.

The General Council has pleasure in presenting to the Members the Report of the work for the year 1927-28.

The membership lists have been revised and the names of all members whose membership has lapsed have been removed. The total number of erasures, due to deaths, resignations, and lapsed membership, is 156, but 249 new members have joined the Institute during the year. There is, therefore, a net increase of 93. The total number of members on the roll on April 30 was 1,729; 13 associate members have been transferred to the grade of member, and six associates have been transferred to associate membership.

The Council regret to announce the deaths of ten members and associate members.

Although a large number of names have been removed from the Roll during the year, a record number of new members has been admitted, and the net increase of membership is one of the largest to be recorded for many years. At the General Council Meeting, held on January 21, 98 applications for Membership and transfers to higher grades were passed. This is one of the largest numbers of new members ever admitted at one Council meeting. As a result of increased membership in the Bristol area, three meetings have been held during the Session for the benefit of members in Bristol and district.

Junior Sections.

There are now Junior Sections in connection with five Branches, namely:—Newcastle, Lancashire, London, Birmingham, and Scottish. The Scottish Junior Section is the latest addition to this number, and was formed in October last at a very largely attended meeting held at the works of Messrs. G. & J. Weir. The Section has held a very successful initial session, and there is every promise of excellent work being carried out in the future.

Oliver Stubbs Gold Medal.

The Sixth Medal was awarded in July last to Professor Thomas Turner, Emeritus Professor of Metallurgy at Birmingham University, for long and devoted services to the Institute.

Diplomas.

Seven Diplomas were awarded in July last for Papers given before the Branches during the previous Session. The recipients and the respective Branches before which the Papers were given are as follows:—Messrs. H. C. Dews (London), J. W. Donaldson (Lancashire), H. V. Grundy and A. Phillips (Lancashire), J. E. Hurst (Sheffield), W. J. Molineux (Newcastle), A. E. Peace (East Midlands), and H. Field (Birmingham).

Annual Conference, 1927.

The Twenty-fourth Annual Convention was held at the University, St. George's Square, Sheffield, in July. Mr. J. T. Goodwin, M.B.E., was installed President at the Convention, which was attended by an exceptionally large number of members and ladies. The President and Council wish to place on record their indebtedness to the Lord Mayor and Lady Mayoress of Sheffield, the Master Cutler and Mistress Cutler and the University authorities for their hospitality and cordial co-operation which helped to make the conference technically and socially successful. The success of the conference was also due to a large extent to the courtesy of the famous firms in Sheffield and District who invited the members to visit their works and to the subscribers to the conference funds.

The next Annual Conference will be held on June 12, 13, 14 and 15 at the Association Hall, Leicester.

General Council.

Four General Council Meetings and a large number of Sub-Committee Meetings have been held during the year at Sheffield, York, Derby and Manchester, respectively. All Branches have been well represented, and there has been an average attendance of 37 at the General Council Meetings. The following Members of the General Council retire at the General Meeting on June 13:—Messrs. A. R. Bartlett, J. R. Hyde, H. Pemberton, G. E. Roberts and J. Shaw. Messrs. Bartlett, Hyde, Pemberton and Shaw offer themselves for re-election.

Test Bar Committee.

Members will be pleased to learn that the revised specification for grey iron castings has now been issued by the British Engineering Standards Association after agreement with the chief Government Departments, railway companies and leading technical societies.

The Test Bar Committee is now investigating the possibilities of the shear test, and hopes to have sufficient information to put before the members so that they can form their own opinion before the matter is again brought forward at the International Convention to be held in London in 1929.

British Cast Iron Research Association.

Although as a consequence of the general industrial situation following the coal strike the increase of members is slow, the British Cast Iron Research Association continues to make steady progress, and its latest development is the completion of arrangements for the Association to have its own melting plant for crucible and cupola melting, facilities for which have been kindly placed at the Association's disposal by one of their members.

A feature of the work during the past year has been the development of large scale practical work in members' foundries, and in particular an important series of cupola tests have been carried out in no less than three works. Over fifty research reports have now been issued by the Association, and their number is steadily increasing.

International Relations.

The relations of the Institute to foreign foundry Associations have been strengthened dur-

MEMBERSHIP, APRIL 30, 1928.

	Subscribing Firms.	Members.	Associate Members.	Associates.	Total.
Birmingham, Coventry, and West Midlands	2 (2)	81 (68)	91 (106)	17 (16)	191 (192)
East Midlands	1 (0)	37 (34)	68 (57)	4 (4)	110 (95)
Lancashire	8 (9)	114 (108)	198 (193)	11 (8)	331 (318)
London	3 (2)	130 (112)	81 (82)	12 (8)	226 (204)
Middlesbrough	4 (4)	31 (26)	27 (27)	5 (8)	67 (65)
Newcastle	10 (10)	56 (67)	52 (60)	77 (72)	195 (209)
Scottish	1 (0)	68 (54)	143 (115)	30 (30)	242 (199)
Sheffield	7 (6)	84 (81)	84 (96)	11 (13)	186 (196)
W. R. of Yorkshire	—	29 (25)	56 (53)	2 (2)	87 (80)
Wales and Monmouth	—	25 (17)	22 (12)	4 (4)	51 (33)
General	—	34 (32)	8 (12)	1 (1)	43 (43)
Total	36 (33)	689 (624)	830 (813)	174 (166)	1,729 (1,636)

The figures in brackets are for the Session 1926-1927.

ing the year. In September of last year a party of members and ladies visited the International Foundry Conference and Exhibition in Paris. Members of the Institute were also present at the European Foundry Congress held in Barcelona in April of this year.

Exchange Papers have been presented on behalf of the Institute to the following Conferences of Overseas Foundry Associations—Dr. A. B. Everest, Spanish Foundry Conference, April, 1928, and Mr. F. A. Melmoth, Conference of American Foundrymen's Association, May, 1928.

Messrs. H. C. Dews and J. W. Donaldson are preparing Papers on behalf of the Institute for presentation to the Belgian and French Foundry Conferences respectively.

Arrangements are already in hand for the International Congress which will be held in London in June, 1929. An International Foundry Exhibition will be held in London at the same time.

Apprentice Training.

The question of training foundry apprentices has been revived and the matter has been referred to the Literary and Awards Committee of the General Council for preliminary consideration. This Committee will in future be known as the Literary, Awards and Education Committee.

Accounts.

The statement of accounts and balance-sheet for the year ended December 31, 1927, are set out on pages 11 to 13. During the year every effort has been made to effect economical working, consistent with efficiency. The income for the year exceeded the expenditure by £120, a result which compares very favourably with the loss of £156 6s. 2d. on the previous year. It is hoped that with an increase of membership and continued economy, sufficient funds will be accumulated to extend the work and usefulness of the Institute.

Increase of Membership.

It has been appreciated by all members that the time has arrived when special efforts should be made to increase the usefulness of the Institute by a substantial increase in the number of members. Considerable efforts in this direction have been made during the past year by the

Branches and by many individual members, and the net increase of 93 shown in the earlier part of this report is the result.

The Council confidently appeals to every member to bring before the notice of non-members the advantages of Membership of the Institute.

The Council desires to express its thanks to all the firms who have arranged for visits to their works and to all those gentlemen who have contributed papers to the Branches and to the annual conference.

J. T. Goodwin, President.
Tom Makemson, General Secretary.

Balance Sheet.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1927.

Expenditure.

				£	s.	d.
Postages				100	0	1
Printing and Stationery, including Printing of Proceedings				542	10	1
Preparation of and Printing and Binding of Indexes				76	2	0
Council, Finance and Annual Meeting Expenses				58	14	4
Medal for Past President				2	6	6
Branch Expenses:—	£	s.	d.			
Lancashire	98	9	6			
Birmingham	61	8	0			
Scottish	80	7	10			
Sheffield	45	18	9			
London	47	14	1			
East Midlands	24	12	0			
Newcastle	102	16	2			
West Riding of Yorkshire	23	10	2			
Wales and Monmouth ..	13	8	0			
Middlesbrough	20	1	0			
				518	5	6
Audit Fee and Accountancy Charges (2 years)				23	2	0
Incidental Expenses				65	5	7
Salaries—Secretary and Clerk..				437	7	7
Rent and Rates of Office, less Received ..				110	3	6
Income Tax				6	10	0
Subscription to International Committee of Foundry Technical Associations				5	0	0
Depreciation of Furniture				6	18	4
				1,952	5	6
Excess Income over Expenditure				120	17	5
				£2,073	2	11

INCOME.

	£	s.	d.
Subscriptions Received	1,976	7	1
Sale of Proceedings, etc.	21	0	6
Interest on War Loan and Cash on Deposit ..	38	14	6
John Surtees Medal Fund Surplus ..	37	0	10
	£2,073	2	11

BALANCE SHEET, DECEMBER 31, 1927.

LIABILITIES.

	£	s.	d.	£	s.	d.
Subscriptions paid in advance ..				103	8	6
Sundry Creditors				411	5	2
The Oliver Stubbs Medal Fund :						
Balance from last Account ..	204	16	4			
Interest to date	8	4	4			
	213	0	8			
Less Cost of Medal..	9	10	0			
				203	10	8
Turner Testimonial Fund :						
Sundry Receipts				72	14	4
Surplus at December 31, 1926 ..	829	19	4			
Add : Excess of Income over Expenditure for year ended December 31, 1927 ..	120	17	5			
				950	16	9
				£1,741	15	5

ASSETS.

	£	s.	d.	£	s.	d.
Cash in hands of Secretaries :						
Lancashire	22	14	2			
Birmingham	14	4	2			
Sheffield	121	6	1			
London	98	1	8			
East Midlands . ..	19	0	9			
West Riding of Yorkshire ..	27	1	4			
Wales and Monmouth ..	1	16	9			
Middlesbrough	18	7	5			
				322	12	4
Lloyds Bank Ltd. :						
General Account	204	10	0			
Deposit Account	400	0	0			
				604	10	0
The Oliver Stubbs Medal Fund :						
£342 5s. 7d. Local Loan £3 per cent. Stock at cost	200	0	0			
Balance in hand, Lloyds Bank, Ltd.	3	10	8			
				203	10	8

ASSETS (*continued.*

	£	s.	d.	£	s.	d.
Turner Testimonial Fund:						
Cash at Bank	71	14	6			
Cash in Hand	0	19	10			
				72	14	4
Investments Account:						
£100 5 per cent. National War Bonds £350 5 per cent. War Loan at cost				432	10	1
Furniture, Fittings and Fixtures:						
Per Last Account	69	2	10			
Less: Depreciation, 10 per cent.	6	18	4			
	62	4	6			
Additions	43	13	6			
				105	18	0
				£1,741	15	5

We have prepared and audited the above Balance Sheet with the Books and Vouchers of the Institute, and certify same to be in accordance therewith.

J. & A. W. SULLY & Co.,
Chartered Accountants,
Auditors.

19/21, Queen Victoria Street,
London, E.C.4. May 7, 1928.

MR. GOODWIN, in referring to the balance-sheet, commented on the considerable saving that had taken place during the past year, with the result that, as against a debit balance of £156 in the previous year, the Institute had a credit balance of £121. (Applause.) That was due to increased membership. They had had a record number of new members.

MR. HIDER (Torquay), in proposing the acceptance of the balance-sheet, made the suggestion that their finances might be considerably augmented if their membership were further increased by vigorous propaganda work throughout the country. He and his son were delighted to travel the long distance from the South to attend the Conference so as to be able to interchange ideas with others; but, unfortunately owing to being such a terrible distance from any other member, that was the only benefit they, as individual members, obtained from the Institute. Their nearest neighbour was 87 miles from them at Yeovil. He pleaded that some propaganda might be done in the West of England. The West of England was not merely a beautiful place but it was also the centre of a string of little foundries and general utility businesses. Exeter had seven; Plymouth had eight, and there were a number of others right down almost to Land's End. He urged on them that the project of increasing the Institute's membership in the West, with the idea of ultimately forming a Western District Branch, should engage the attention of the Council and their excellent Secretary. (Applause.)

Mr. Harley (Coventry), in seconding the motion, desired to support the compliment that had been paid not only to the Branch Secretaries but to their General Secretary, who must have had a very hard year. They must all acknowledge that he had been remarkably successful in the results.

The resolution was carried unanimously.

Election of Officers for 1928-29.

President.

Mr. Goodwin said that the Council yesterday had unanimously passed a resolution that the Senior Vice-President (Mr. S. H. Russell) should be nominated President for the ensuing year. As the retiring President, he had the honour of proposing that that recommendation of the Council be accepted. In Mr. Russell they would have one who would more than further the interests of their Institute. He was a keen, hard-working and enthusiastic member of the Institute. (Applause.) He had the advantage of being associated with one of the most important iron foundries in Leicester. (Applause.) Mr. Russell knew very well the responsibility he had to take hold of in his new office. He had helped him (the speaker) considerably during his term of office on all kinds of difficult points, which did not always come before either the Council or the members as a whole.

Mr. F. J. Cook, the senior of the Past-Presidents, in seconding, said that he had known Mr. Russell through the agency of their Association for a great many years, and had always looked upon him as one who, in due course, would worthily fulfil the office for which he was being proposed. He could endorse all that the President had said with regard to the abilities of Mr. Russell to fulfil the duties which were expected of him, and he was sure that, at the end of his term, he would have covered himself with glory and have occupied the post to their entire satisfaction.

The resolution was passed with great enthusiasm. Mr. Goodwin then invested Mr. Russell with the President's Chain of Office, and the latter formally occupied the chair amid loud cheers.

The PRESIDENT (Mr. S. H. Russell), in expressing appreciation at his election, assured them that he felt a very great and very high honour had been conferred on him. He realised that he was following in the steps of some of the most famous men in their industry, men who by patience, perseverance, and often under great difficulties, had done much research work, and had given the benefit of that work to the industry generally, with profit to the members. He could claim no such distinction. All he could say was that he had benefited very much indeed by his membership of the Institute, by his fellowship and association with all the members at different meetings, and particularly in meetings at his own branch, so that, in his occupancy of that post, it was only due to them to attempt to make some small return for the many benefits that he had received from his connection with the Institute. He was very deeply interested in its work, and he would promise them that he would do his best. He hoped that, when the end of his term came, he would have as good a record as their immediately retiring President, Mr. Goodwin.

Vote of thanks to ex-President.

The PRESIDENT said that his first duty was to express their very hearty and sincere thanks to Mr. Goodwin for the extremely able way in which he had conducted the affairs of the Institute during last year. Mr. Goodwin was certainly the man to tackle what was always a difficult problem, the problem of finance, and they could congratulate him heartily upon the splendid recovery which had been made. At Sheffield some of them were a little despondent. There was an adverse balance, and trade was bad. Mr. Goodwin had wholeheartedly tackled the problem of finance, and, with the assistance of Mr. Makemson, the Institute had made a splendid financial recovery as a result. In practically every feature of the work of the Institute, Mr. Goodwin had shown an unbounded enthusiasm. He had not spared himself in the least. In fact, Mrs. Goodwin, he rather understood, felt a slight resentment at the amount of work Mr. Goodwin had put in on behalf of the Association, and he was sure they all ought to express to Mrs. Goodwin their very sincere thanks for what he had done. (Applause.)

Mr. Cook, in seconding, said that the work of the President became more onerous every year as the Institute grew, especially with regard to finance. The expenses were very great, and they were handling quite an appreciable amount of money. It required an amount of exceptional executive ability, as well as being a good foundryman, to govern and rule over them in the capacity of President. The least they could do was to thank him most heartily for having undertaken the work on their behalf. He had great pleasure in seconding the vote of thanks.

The motion was carried with acclamation.

Presentation of Medal to Past President.

The President said there was one pleasant function which remained after thanking the Past President for his services, which was to hand to Mr. Goodwin, as a little souvenir of his year of office, the replica of the badge. He hoped that, although Mr. Goodwin might have found the work arduous, that memento would remind him of the many happy times he had had, and would act as some slight reward and return for the services he had rendered. (Prolonged applause.)

Mr. Goodwin, in responding, thanked them all for the kindly words which had been said, which more than amply rewarded him for the work he had done for the Institute. The generous way in which the members had all shown their appreciation by their applause had heartened him very much. He felt leaving the Presidential chair very much indeed; but the expression of esteem which they had given him certainly recompensed him for having to relinquish an office which he had thoroughly enjoyed filling. He thought during the debates, in Council and elsewhere, they appreciated that every move that he had made had been in the interests of the Institute, and not from any personal feeling of his own. (Applause.)

Vice-Presidents.

The President said the office of President next year was going to be a highly important one, because they would be visited by an Overseas delegation, which would number about 300.. He had the greatest possible pleasure in nominating Mr. Wesley Lambert as their senior Vice-President. He was particularly delighted to do that, because it was greatly to the interests of the Institute to have a non-ferrous man so well known as Mr. Lambert was in connection with non-ferrous work in the chair. They tended a little to concentrate on the cast-iron side, in which side no doubt the majority of their members were interested; but there was much important work to be done on the non-ferrous side; and from that point of view, therefore he was pleased that they had Mr. Wesley Lambert to step into that office.

Mr. Faulkner (Past-President) seconded with the greatest pleasure the proposal to elect his colleague in the London branch as senior Vice-President of the Institute. Mr. Lambert had achieved an international reputation as a non-ferrous metallurgist. He had not merely sat upon most of their committees, but had directed them during the last two or three years. Furthermore, in co-operation with his colleagues in the London branch, he had raised that particular section of the Institute from a condition bordering upon being derelict to the position which it occupied as the premier branch of the Institute. (Loud applause.) In general membership it was not quite as large as others, but in the amount of money it sent to the Central Office it certainly was first, though to say that might sound a little ungracious to the branch whose hospitality they were enjoying. Mr. Lambert had also attended several international gatherings, and had presented a Paper on their behalf to the American Association. They were not merely honouring Mr. Lambert in asking him to be their senior Vice-President, but they were also honouring themselves. It was a reciprocal arrangement, and one which it gave him very great pleasure to second.

Mr. Goodwin also supported the nomination.

The motion was carried with enthusiasm.

Mr. Wesley Lambert, in returning thanks, said he was very pleased to accept the office, which he did fully conscious of the fact that, if everything went right, and when in due course he took the position of the chair, he had to look forward to a very, very onerous presidential year of office. That year of office would include the International Conference. They would imagine his feelings when he had heard that it was not at all unlikely that no less than 200 Americans would be coming to attend that Conference, to say nothing of a large contingent from the Continent. At the same time, knowing the London branch, and particularly the secretary of the London branch, and knowing the Council, he had no hesitation whatever in taking office, because he felt sure the London branch would not let him down when it came to the International Conference. (Applause.) They were working very hard indeed to make that Conference a huge success, so that it would redound to the honour and glory of the Institute of British Foundrymen. That could not be done unless they had the whole-hearted support of every member of the Institute. He felt sure that the acclamation with which they had received his nomination was an expression of their willingness to give him and the London branch the assistance which they would certainly need when the International Conference came along. (Applause.)

Mr. H. Winterton (Glasgow) then moved the nomination of Mr. F. P. Wilson, of Middlesbrough, as junior Vice-President. It was in 1907 that he had visited Middlesbrough for the Conference, and he had a distinct recollection of the excellent time they had there. Mr. Wilson was the past president of the Middlesbrough Branch. The time had come when they should pay another visit to Middlesbrough, and he was sure both Mr. Wilson and his colleagues would do their best to provide them with a good conference in due time at Middlesbrough.

Mr. J. Cameron (a Past-President) seconded the motion. They would remember it was a very interesting duty of the President when the opportunity came to visit a body of ironfounders who wished to form a new branch. That was the great privilege he had had in his year of office. He was heartily supported in that by Mr. Patterson, his immediate predecessor, of the Newcastle branch. They both went to Middlesbrough, and Mr. Wilson took a prominent part in creating the Middlesbrough branch. He and Mr. Ridsdale, the capable secretary, did everything in their power to make the meeting a success; and the result of the opening meeting on the Saturday evening was that something like 80 names were handed in. It was a great pleasure to him to find that new branch doing so well as to be able in such a short time to put up a president of their own.

The motion was put and carried with acclamation.

Mr. F. P. Wilson, in responding, remarked that he was probably quite unknown to the bulk of the members, and, in electing him to that office, they had backed a dark horse. (Laughter.) He was very greatly surprised when, at the Council meeting last night, the suggestion had been made. It was the very last thing that he had in mind in coming to Leicester, and had he suspected it might happen he probably would not have been there at all. He felt, however, when pressure was put upon him, that it was not a personal matter, but was a matter of the good which one sought for one's own branch in particular, and, of course, for the good of the Institute as a whole. The Middlesbrough branch was very young, but they felt that a district like Middlesbrough should support a strong branch of the Institute. If, by a visit of this Convention to Middlesbrough, something could be done to elevate the foundry trade as a whole in that town and raise them from the position which most people in the Midlands and the South considered they occupied—he was afraid they were rather looked upon as savages—it would be a great advantage. No doubt it would help to enlighten and civilise them a little to have a visit from such a body as the Institute. He felt quite unfitted for the position; but, if it was their wish that he should occupy it, he felt, as a matter of duty, that he could not refuse to do so. (Applause.)

Presentation of "Oliver Stubbs" Gold Medal.

The President said that the next item on the agenda was the award of the "Oliver Stubbs" medal. After considering the matter very carefully, the Literary and Awards Committee had recommended to the General Council that the "Oliver Stubbs" medal should be awarded to Mr. J. W. Donaldson, B.Sc., A.I.C., of Greenock, who had contributed many Papers to the "Proceedings" of the Institute, embodying his researches upon cast iron. As Mr. Donaldson was unfortunately unable to be present the medal was formally handed to Mr. Winterton, who promised to convey it, with the felicitations of the Convention, to Mr. Donaldson.

Diplomas.

The Secretary stated that diplomas had been awarded to the following gentlemen in connection with Papers laid before the Branches during the past session:—Mr. A. J. Beck, for his Paper on "Some Methods of Production in the Modern Malleable Iron Foundry"; Mr. F. Hudson, for his Paper on "Scottish Moulding Sands,"; Mr. P. A. Russell, B.Sc., for his Paper on "Shrinkage Holes in Small Grey Iron Castings"; Mr. N. D. Ridsdale, for his Paper on "Practical Moulding Sand Control"; Mr. W. H. Poole, for his Paper on "Cupola Practice."

Trustees.

On the proposition of the President, seconded by Mr. Faulkner, the following were re-elected Trustees of the Institute:—Mr. F. J. Cook, Mr. Oliver Stubbs and Mr. R. O. Patterson.

Re-election of Auditors.

On the motion of the President, seconded by Mr. Cook, Messrs. J. & A. W. Sully & Company (chartered accountants) were re-elected auditors.

Hon. Treasurer.

On the motion of Mr. Cook, seconded by Mr. Stevenson, Mr. F. W. Finch was re-elected Hon. Treasurer, Mr. Cook remarking that, as he had served his apprenticeship under Mr. Finch, he could claim to know something about him, as he had known him for a very long time.

On the motion being carried, the PRESIDENT remarked that they would be interested to know that they had just received a message of good wishes from their old friend, Mr. Finch, whose health did not permit him to attend the meetings.

Members of Council.

As the result of the ballot to fill the five vacancies on the General Council, the following were re-elected:—Mr. Bartlett (London), Mr. A. R. Campion (Scotland), Mr. J. R. Hyde (Sheffield), Mr. H. Pemberton (East Midlands) and Mr. John Shaw (London).

Buchanan Medal Donation.

MR. GOODWIN said that he had been asked by the President to state to the Conference the terms of the donation in connection with what was known as the Buchanan medal. It was an exceedingly great pleasure to him that, during his year of office, the memory of their first President should be honoured by an anonymous donor, who wished Mr. Buchanan's memory to be perpetuated. Mr. Buchanan was one of the pioneers of foundry research. Mr. Buchanan had had considerable difficulty, with others, in bringing these matters to a technical head; but they were very grateful for the work he had done. It was acknowledged to be the foundation of the work they were carrying on. Even in his later years, Mr. Buchanan was ever wishful to help those who were in difficulties with foundry matters. The conditions of the awarding of the medals briefly were these: That the medals should be given to the Junior Branches only, one medal for each Branch. Any member of a Junior Branch who wished to compete for the medal must write an essay, giving a *résumé* of the work done in the particular Branch of which he was a member during the session. At a certain time an examination would take place, which would be conducted by the Literary and Awards Committee with the supervision of the Council. The conditions were practically the same as the conditions of the "Oliver Stubbs" medal. He would read a letter from the Midland Bank which summed up the whole position: "Dear Sir,—We have the pleasure to inform you that we have received instructions to purchase £125 worth of 3½ Per Cent. Conversion Loan on behalf of your Institute, the dividends to provide annually the Buchanan medals in silver under the scheme with which you have already been acquainted. We shall be glad to have the names of the Trustees, together with specimen signatures. Our client suggests that those Trustees should be the President, the President-Designate, and the Secretary of the Institute of British Foundrymen, any two of whom shall have authority for effective signature. Kindly complete and return to us the enclosed form.—Signed, F. Burrows, the Accountant for the Bank." The die from which those medals would be made in future—also a gift—would also become the property of the Institution. That was a great asset, as it left the money quite free to be spent on these medals. He was very delighted that the donor had thought fit during his year of office to negotiate with him, through the Literary and Awards Committee, for the carrying into effect of this splendid donation on his part. (Applause.)

The President, in accepting that handsome gift, moved that they accept the donation to form a fund for the Buchanan medals, and that they also expressed to the anonymous donor their very hearty thanks for the fund which he had generously handed over to them to provide these medals for competition year by year among the junior members. (Loud applause.)

Mr. B. Hird (South Wales), in seconding, said that Mr. Buchanan, a good many years ago, was a very kind friend to him, and helped him considerably. He would like to thank the donor for doing something which he had felt, had he been in the position to do so, it would have been an appropriate thing for him to have done, because Mr. Buchanan had helped along many struggling members in the years that had gone by.

The motion was carried with enthusiasm.

The President said he presumed they would accept as the three Trustees the President, the President-Designate, and the Secretary of the

I.B.F. (Agreed.) He took it that the Trustees would change as the officers changed, so that there would be no risk of difficulties arising through the passing away of any of the Trustees.

Presidential Address.

Mr. S. H. Russell then delivered his Presidential Address.

Mr. Goodwin and Gentlemen,

I feel that the members have every reason to be satisfied with the progress of the Institute during the past year. When we met at Sheffield we had just completed the first year with our secretary and offices at Manchester, and many of us were afraid that a retrograde step had been taken. I believe that at Sheffield we all realised that the move was a wise one, but that there were still many difficulties ahead of us, mainly owing to the increased expenditure incurred. The thanks of the Institute are due to Mr. Goodwin for the courageous way in which he tackled this problem, and the very satisfactory improvement which has been made in our finance is due mainly to the increase in our membership, to which both Mr. Goodwin and Mr. Makemson have devoted much of their time and energy. We need still larger funds at headquarters to carry out adequately all the work the Institute should do, but I have every confidence that we shall still further increase our membership, and that we may hope for an increase in the number of subscribing firms and in the transfer of associate members to full membership. In my opinion no foundryman can afford to stay outside the organisation.

The members of this Institute are under a deep debt of gratitude to the members of the Council for the splendid attendances they make at the Council meetings. Our Branches are scattered all over England and Southern Scotland, many members have to travel long distances, usually at their own expense, and have to give up their Saturday, and yet we get attendances of 35 to 40 at our meetings, thus proving their interest in the Institute.

In October last care was taken to appoint subcommittees which were really representative, and I believe these committees have functioned more to the satisfaction of the Council than has been the case on some occasions.

As regards the individual member, the value of the Institute depends considerably upon the Branch to which he is attached, and as to whether he attends their meetings or not.

A newly-elected President has very little opportunity of knowing the workings of any Branch other than his own, and during his year of office he usually visits other Branches at their annual dinner, at which the atmosphere is certainly different from that of an ordinary meeting, often held in a lecture room in which the seats are not designed for comfort.

Branch Programmes.

Upon the Councils of the various Branches rests a heavy responsibility as to the papers presented to their members, and I wish to urge upon all Branch Presidents, Secretaries and members of Council the necessity of obtaining good programmes, and of taking every possible step to encourage what is generally known as the discussion, and also to develop a feeling of comradeship amongst the members. In connection with this works visits are an important item. It is not always that the actual visit to the works is of great value to certain members who are in another section of the industry, but the opportunity of meeting and discussing with other men, some of them experts, in this informal way, is of very great value. It is encouraging to find a reference to one or more works visits per session in the Branch programmes, and I hope that those Branches who have made no reference to same have arranged such functions, and that they have been well supported by their members.

With further reference to the question of papers presented to the Branch meetings, I would suggest that a mistake is sometimes made in endeavouring to obtain a large proportion of original papers. There are 13 Branches (excluding Junior Branches) at which on the average 6 papers are presented per annum. This means, if every one is original, and presented at one Branch only, 78 papers per annum (in addition to those presented at the annual conference) are given.

I am aware that the number of problems in foundries is almost infinite, but with all due respect to our members, I do not think we can expect anything like 78 original papers every year.

Again, many of the papers read before the Branches are the fruit of much study and experience, usually illustrated by lantern slides, diagrams or samples, and yet even when awarded a diploma many of these papers are presented only once, and their value to the industry is mainly lost. It will greatly encourage the author of a really good and original paper if he is invited to present it to another Branch, and it will probably mean that as the result of previous criticisms the paper will be improved, and of even more value when read a second time. Will Branch Councils when drafting this next programme consider my argument and see whether they cannot include some of the papers which have been awarded diplomas this year?

One other thing, whilst on the topic of Branches; it is disquieting to read in the report of the annual meeting of one of our largest and oldest Branches that there were no retiring members of Branch Council, occasional vacancies having been filled up in previous years for the full period of three years. In justice, I must add that the matter of a number retiring each year is to be reconsidered, but I believe that the life and soul of a Branch is its Council, and that it is essential that every year members should have an opportunity of introducing fresh stock if in their wisdom they deem it advisable. I have obtained much pleasure, and, may I say, a little wisdom, from being actively associated with my own Branch, and I am anxious that all other members shall have every opportunity of enjoying the privileges and advantages I have had.

An Entrance Examination.

The Literary and Education Committee have before them two very interesting and important matters, which they have to consider during the next year. The first of these is the suggestion several times made, but becoming more insistent, that some form of examination should be passed before new members are admitted to the Institute.

This really is a move to raise the status of membership in our Institute, and is very desirable. Our title clearly indicates the qualification necessary, that of a foundryman. But it is a difficult thing to put into writing exactly what qualifications are necessary before one can claim that name. You will find men mixing and alloying white metals. and who never use a sand mould from one week-end to another, others working loam, and with the aid of a few strickles and a blue-print producing very successfully large castings in iron or bronze, others who specialise in mass-production methods, and who produce enormous quantities of a few articles, often, again, without using a sand mould, though they may use sand cores, and, lastly, all those who supply the necessary raw materials for the industry, many of them not foundrymen in one sense of the word, and yet having a specialised knowledge of one or other section of the industry. If you attempt to frame a set of questions which you may expect a jobbing foundryman to answer, can you hope that men engaged in these more specialised branches can answer them satisfactorily. In some societies it is necessary for a candidate to write a thesis on some branch of the industry, but many of our worthiest members are craftsmen, who have no literary gift, and it seems to me that when the time is ripe for this development considerable thought and care will be necessary in deciding what tests are to be applied to candidates for election.

A National Certificate.

The other and probably more pressing matter is the question of a national examination in foundry practice, and I am sure that it is very gratifying to all our members that the enterprising Editor of our official organ, The Foundry Trade Journal, has appointed a special commissioner, who will visit every important educational centre, and will report upon the facilities which at present exist for the scientific and technical training of future foundrymen. In reading through the first article on this subject (published on May 10 last) I gather that a slight confusion exists. The Institute proposes at the moment to request the City and Guilds of London Institute or other authoritative educational body to carry out the examination of candidates attending the various foundry classes up and down the country, so that instead of the local certificate issued to successful candidates, a national certificate will be issued which will naturally carry much more weight. It appears to me that students attending a University or University college will require a higher form of certificate than this, and probably the Institute will have to adopt a scheme such as is already carried out by kindred societies, to cater for what I may term the more advanced type of student.

In other words, the Institute proposes, with the assistance of the City and Guilds of London Institute, to arrange for a national certificate to be competed for by persons training at evening schools or on a part-time scheme, and has yet to tackle the other problem of a suitable award or diploma which will carry national recognition, and entitle the owner to be recognised as a fully-qualified foundryman, capable of stepping immediately into an executive position.

To assist in the promotion of either of these schemes it will be helpful to our Institute to have first-hand and up-to-date information on existing educational facilities both at our University Colleges and at our Schools of Technology, and we welcome the assistance of THE FOUNDRY TRADE JOURNAL in this direction.

Very much akin to this subject is the question of the training of foundry apprentices, and I consider that our worthy secretary, Mr. Makemson, has made a very valuable contribution to this problem in the Paper he has presented to one or two of our Branches during the last session. In connection with this matter one difficulty I have not seen commented upon is that many of the modern and progressive executives engaged in foundry work are concentrating upon mass production, methods which tend to eliminate the skilled moulder, and, in fact, all craftsmanship. These firms can probably obtain the type of labour they require with less difficulty than the foundryman who has to rely upon the skill of the moulder to produce satisfactory castings. It is easier and more remunerative to-day to produce a limited variety of castings in large numbers, than it is to produce a larger variety of castings in limited numbers, and, speaking broadly, I believe I am right in saying that the works producing this second type of casting are smaller and less well-organised than the other section of the industry. so that some of the men to whom we look for leadership and help do not feel the necessity for the long-overdue improvement in the quality of foundry apprentices, whilst others to whom the need is so much more pressing seem incapable of taking the bold and resolute steps necessary to effect an improvement.

The Work of the B.C.I.R.A.

One of the objects of our Institute is to initiate, conduct, and supervise researches, all as set out in paragraph d, section 1, of the by-laws. As you all know, the practical outcome of this was the formation of the Cast Iron Research Association, which has now been functioning for over six years. Real and accurate research work is necessarily slow, and some of us tend to be impatient because the Association has not yet set the Thames on fire. Mr. Pearce, its director, informs me that during the past year the most notable feature of the work of the Association has been the extension of work of a practical character. In connection with cupola melting economy, the Association has produced a new design which offers exceptional means for control, and which in working is giving quite unusual melting economies. In addition to this, a series of tests are being made in conjunction with Mr. R. O. Patterson on various cupola cokes, by means of which differences between different types of coke, different grade sizes, and different methods of manufacture are being shown to have a definite influence on melting rate and economy. A similar series of tests on different cupola linings is in active preparation. Certain proprietary cupola designs have been examined, and tests supervised for the benefit of members. Practical melts have also been made on light casting irons with a view to determining the influence of constitution of strength.

Work on moulding sands and on malleable cast iron has been proceeding actively, and notable progress has been made in connection with the influence of nickel on cast iron. One of the most interesting developments during the year has been that of a special alloy cast iron, which is, under certain corrosive agents, virtually corrosion-proof.

If I may venture a criticism it is this. The report issued by the Government Department Commissioners was very favourable, but had one unfortunate and rather unlooked for effect, and that was the insistence upon the appointment of a further fully qualified scientific member of the staff, at a time when the funds of the Association did not permit them to also employ additional help upon the practical side. There are two or three men in this country, at present employed as experts or in an advisory capacity by commercial firms, any one of whom could help the industry far better if they were members of the staff of the Research Association, and it is unfortunate that this recommendation was insisted upon by the Department concerned at such a time.

Foreign Relationship.

It is very pleasing to note the close contact maintained with foreign societies, not only through the Exchange Papers, but also through visits to their conferences, and the successful functioning of the International Committee is very gratifying. The thanks of the Institute are due to Mr. Faulkner and to Mr. Makemson for the invaluable work they do in this connection. We are looking forward to receiving a visit next year from overseas foundrymen, and a preliminary programme embracing a three weeks' tour of Great Britain is already in the hands of our foreign friends. We are all looking to the Branches doing their share towards entertaining these guests, and letting them see that the foundries in Great Britain are more progressive and capable than some of our pessimists would have us believe. This tour culminates in London, where we are holding our next Convention, and where simultaneously will be staged an International Foundry Exhibition.

Members will have gathered from the annual report that the Test Bar Committee have successfully completed the first part of their labours, and we are glad to learn that the new B.E.S.A. specification is based largely upon their recommendations.

Junior Sections.

Last, but not least, may I make a brief reference to the Junior Sections? We now have five of these, and as far as I can gather from reports they are all in a flourishing condition. It is a very happy thought of the anonymous donor to offer Buchanan medals for competition amongst the members of our Junior Branches, and I am particularly delighted that Robert Buchanan's memory should be commemorated in such a happy way. We all remember his genial personality and his kindly manner, he had a deep knowledge of the craft, and was always ready to give advice and assistance. He was our first President (1904-1905), he maintained his interest in the Institute right up to the end, and I am sure that no more suitable way can be imagined for perpetuating the memory of this lovable man.

I am entering upon my year of office full of hope and confidence that our Institute will continue to maintain progress, not only in numbers, but also in status, and I am sure that I can rely upon the support of every member in doing his best to make the present year one of real progress, so that when our friends from overseas are present at the next Convention they will find an Institute second to none in this country of ours.

Vote of Thanks to the President.

Mr. John T. Goodwin (Past-President), in proposing a very hearty vote of thanks to the President for his excellent Presidential Address, remarked that never in his experience of the Institute had he heard an address which so clearly conveyed to them the enormous work that the Institute was doing, and which showed such a thorough grasp as their President had of the work that should be done.

Mr. Wesley Lambert formally seconded.

The vote of thanks was carried with enthusiasm.

The President briefly responded.

Technical Exhibits at International Conference.

Mr. Wesley Lambert reminded them that the President had mentioned in his Address that a Technical Exhibition would be held at the time of the International Conference in London. At the former exhibition held in London they had had a

Technical Exhibition, and he had the honour of being the Chairman of the Committee which had arranged that. It was proposed to do something on an even larger scale than had been arranged on that occasion. Judging from the numbers of letters he had received, that portion of the Exhibition appealed very much indeed to the members of the Institute. He was hoping they would all give very deep consideration to the Technical Exhibit, so that when they were called upon, they would be in a position to tell them what they were prepared to offer. Those who attended the London Exhibition would remember the class of exhibit that he was referring to. They wanted particularly typical castings and typical failures, so that one had an opportunity of seeing the difficulties that those engaged in every section of the industry were up against. In that way they were in a much better position to make comments at discussions and to educate themselves. They hoped that the Technical Exhibit at the coming Foundry Trade Exhibition would be a very successful one, and on a fine scale.

The President supported Mr. Lambert in his request, but he expected everyone would have much less difficulty in supplying Mr. Lambert and his Committee with typical failures than with typical castings. (Laughter.)

The following Papers were then read and discussed:—

"A Study of the Shrinkage in an Iron Casting," by Maurice Servais. Presented on behalf of the Association Technique de Fonderie de France.

"Malleable Castings," by W. T. Evans and A. E. Peace (members).

During the afternoon a party of members travelled by special train to Stanton Gate Station and visited the works of the Stanton Iron Works Company, Limited. The visitors were entertained to lunch by the company, and at the conclusion of the visit the thanks of the party was extended to the directors for the facilities offered in connection with the visit and for their hospitality.

Other parties of members visited the works of the British Thomson-Houston Company, Limited, at Rugby, and Messrs. Wadkin & Company, Limited, Leicester. Both companies kindly entertained the respective parties to afternoon tea, and at the conclusion of each visit the thanks of the party was extended to the management.

In the morning the ladies visited the works of Messrs. N. Corah & Sons, Limited, hosiery manufacturers, and in the afternoon they took part in a motor-coach excursion to Belvoir by invitation of the Convention Committee.

ANNUAL CONVENTION BANQUET.

WEDNESDAY, JUNE 13.

There was a gathering of some 200 members and guests at the Annual Convention Dinner, which was held at the Oriental Hotel, Leicester, on Wednesday, June 13. The President was in the chair; and the guests included the Mayor of Leicester (Alderman J. Thomas), the Mayor of Loughborough; Mr. E. J. Fox, Mr. Charles Benion, J.P., Mr. H. Winterton (President of the Foundry Equipment and Supplies Association), Mr. J. G. Pearce (director of the British Cast-Iron Research Association), and Capt. Crewdson (deputy chairman, FOUNDRY TRADE JOURNAL).

Trade and Commerce of the City of Leicester.

The Loyal Toast having been duly honoured, MR. WESLEY LAMBERT (Senior Vice-President) in proposing the toast of "The Trade and Commerce of the City of Leicester," said it was an honour which he fully appreciated to be entrusted with that toast, which he was sure they would all heartily receive. He was certain he was voicing their feelings when he said they were delighted and honoured in having the Mayor and Mayoress of Leicester with them. They would support him also in the wish that on some future occasion, when that toast was being proposed and the Mayor had to respond, the mode of address of that gentleman would be "The Right Honourable The Lord Mayor of Leicester." (Applause.) The fact that the Mayor had to respond to the toast had somewhat awed him. It reminded him of an incident which occurred when the late Sir William Harcourt and Mr. Gladstone were at a public meeting together, and speeches were demanded from them. The former gentleman excused himself by saying that to mix wine with water was to spoil both, and as Mr. Gladstone was to supply the wine, he did not propose to offer the water. They, he was sure, were expecting to have the wine from the Mayor of Leicester. The only excuse he had for saying anything at all in support of that toast lay in the fact that a sip of water sometimes prepared the palate for good wine. (Applause.) He was more familiar with the name of that City than perhaps with that of any other Provincial City in the United Kingdom, by virtue of the fact that there was a financial gentleman who addressed almost daily to his wife letters bearing the postmark of Leicester. (Loud laughter.) That gentleman's intelligence department must be very much alive, because he had surprised what was a domestic secret, namely, that any surplus money after his own modest needs were met, was claimed as a perquisite by his wife. (Laughter.) He was particularly pleased to have the opportunity of proposing the toast because as a Londoner it gave him an opportunity of thanking both the hosiery and shoe trades of Leicester for their very worthy efforts towards creating a brighter London. (Loud laughter.) He was neither too young nor too old not to appreciate that effort, though he sometimes thought on certain unrehearsed occasions the silken hose of Leicester was in somewhat too much evidence. (Laughter.) He must plead ignorance because as a technical man he did not know the difference between trade and commerce, and his good friend on the left, on being asked, had suggested that they were both the same. He hoped that the prosperity which had hitherto been experienced by the City of Leicester and the county as a whole would continue, and that the trade and commerce of that ancient city, which he gathered had more industries of a different character than any other city in the United Kingdom, would maintain its good record in that respect.

Leicester's Many Activities.

The Mayor of Leicester, after thanking them for the kind and courteous way in which they had received the toast, said Mr. Wesley Lambert seemed a bit uncertain as to the difference between trade and commerce. His definition of those terms was that the man who was in trade was the man who transformed and worked the raw material into the finished article. The commercial part of it was the part of the salesman and man who organised the sale and disposal of the finished article. The industries in Leicester were such that they were in a position to clothe the whole of the civilised world from head to foot. Their main industries were boots and hosiery, and amongst other things, as had been hinted at, they produced silk stockings. He always said if a girl paid 10s. for a pair of silk stockings and could only show 9s. worth of them, she was disappointed. (Laughter.) Another thing they could be proud of was the fact that in such times of trade depression as they were going through, they never felt the pinch in Leicester like it had been felt in other industrial towns, owing to the large number of their industries. That was how it was that the working classes in Leicester did not feel the pinch. They had less unemployment in Leicester than in any other city of its size in the Kingdom. He would guarantee that there was no man and woman present at that gathering who had seen a man, woman or child badly dressed in Leicester. There were organisations in Leicester which supplied the demands in cases of necessity or want or distress in any circumstances. Leicester, as to its civic and benevolent institutions, might rightly be described as the University of England. They had quite a number of iron-founders and large engineering works, whilst the largest hosiery factory in the world, and the largest shoe machinery works in the Kingdom were to be found in their city.

The Institute of British Foundrymen.

This toast was listed under the name of Sir Henry Fowler, K.B.E., LL.D., but unfortunately Sir Henry was unable to attend at the last moment, owing to an urgent engagement arising with the Ministry of Transport. In the circumstances Mr. E. J. Fox (President-elect of the National Federation of Iron and Steel Manufacturers) stepped into the breach.

Mr. E. J. Fox, in proposing the toast, remarked that he was in a position of considerable difficulty. Their President had paid him the compliment of asking him to reply to the toast of "The Visitors," in conjunction with his Worship the Mayor of Loughborough, and he would make no secret of the fact that he had been at some little pains in preparing suitable things to say on that subject. However, all that had gone by the board, and the only consolation he was left with was that he had been able to relegate that duty to the Mayor of Loughborough. Passing from frivolous thoughts to serious thoughts, the toast he had the honour to propose of "The Institute of British Foundrymen," was indeed a toast of the greatest seriousness. He would ask them to travel with him for a few minutes in trying to analyse the position of their great iron industry. There were several in that room interested primarily on the side of producers of iron, a commodity of which the bulk of those in the room were consumers. He would just like to ask the question: "What is wrong with the iron industry in Great Britain?" It was an industry which was sometimes overshadowed by the industry of steel. But in point of fact, the iron industry, from almost every point of view, was of far greater importance, particularly from the employment point of view, than its cousin, the steel industry. The output of the iron industry in Great Britain measured by tons was somewhere about the same as the output of steel. But there was this big difference between the two: that for every ton of pig-iron produced somewhere between 6 and 7 tons of materials were mined, quarried or produced. In other words, they must multiply the output of pig-iron by 6½ or 7 to arrive at the importance of the industry from a national point of view.

A Sick Industry.

Having emphasised the importance of the industry to the country, he would ask what was the condition in which they found it to-day? In the first place only some 60 or 70 per cent. of the blast furnace capacity was operating. What was a good deal more serious was that the pig-iron production to-day was less than it was 50 years ago. When one carried one's mind back to the developments in the iron and steel trade which had taken place during the past half-century, they would realise how grave the position was when he told them they were actually smaller producers of that basic commodity than they were in 1880. Going back not quite so far as that, but going back to the pre-war year 1913, taking 100 as the standard of 1913, the output to-day was 71, so that they had dropped back nearly 30 points since the war. The output of Belgium instead of being 100 was 152, the Saar 131, Germany 122, U.S.A. 112, then Great Britain 71. The only consolation they were left with was in the knowledge that Russia was below them with 70, as against their 71, and Poland was below them with 63 as against 71. They could derive a little consolation from the knowledge that at last the authorities who were governing over them had realised that something had to be done to put their basic industries on to their feet again as an alternative to handing over the reins altogether to the Continent. He had missed one important point in asking the question what was wrong with the pig-iron producing industry. He had omitted to tell them that in point of fact pig-iron was being produced, and was available in Great Britain cheaper than in any country in the world outside India. (Applause.)

To answer the question what was wrong with the pig-iron producing industry, obviously there could only be one answer, namely, that the pig-iron producing industry required resuscitating, and required to be brought into real being again as well as its consumers. How to achieve that he did not know. Whether the remedy required was Protection or what it was, it was not for him to say, but he was convinced that most industries such as theirs, big employers of labour per unit of output produced, could not possibly compete, as they were attempting to do to-day, with the Continent, where the rates of wages were between half and two-thirds cheaper than the rates of wages they were paying in their own country. He had asked himself the question was there anything that the pig-iron producers could do to attempt to help the pig-iron consumers. Two points he was going to refer to, without he hoped it being considered presumptuous on his part, were those in connection with the founding business.

Coke Ratios in Cupola Practice.

Although he was a pig-iron producer the interests he was associated with were big consumers of pig-iron, big re-melters of pig-iron, to the extent of some 6,000 tons per week. The first of those two points was this: In many cases a great deal more fuel was consumed in re-melting iron than was necessary. (Applause.) At Stanton they operated cupolas with a percentage of fusion coke from 6 to 7 per cent. per ton of metal re-melted, the normal being taken at somewhere about 10 per cent. He might say that 10 per cent. was good practice; but with the volume of iron they had to re-melt, with the particular class of commodity with which they were dealing, unless they did get to the lowest decimal point of efficiency, they would have the very greatest difficulty in competing against their rivals on the Continent. He could not help feeling that in that one direction there was room for economy. They need not look for any improvements by adopting any quack medicines, but all they need do was to follow the principles and practice which had been known for many years. As to the new patents which came to one from the Continent they had tried them out, but they had not made any money out of them. He felt the Institute was doing remarkably valuable work in the direction of investigating problems of a technical nature in connection with iron founding which only a few years ago were poorly thought of, but which then were being tackled on really scientific lines. The Institute was very much to be congratulated on what they had already done in that direction; and they should be encouraged to carry that issue of their work a good deal further.

Potentialities of Ordinary Iron.

His second point was directly linked up with their analytical and scientific work. He thought there was a great deal more money thrown away in iron founding on the assumption that expensive special irons were necessary than in point of fact was actually the case in practice. If one took any of the cheap good brands of Derbyshire iron, with the knowledge on which they prided themselves, one could get results from their cupolas which would in every respect compete against mixtures which had very largely in the past been made out of so-called special irons. Speaking on behalf of the pig-iron producers, he could say that they would welcome co-operation on technical lines between themselves and the metallurgists and foundry managers. If that co-operation were a little bit more intimate and a little bit more extensive, he could not help feeling that they would succeed in aiding them to produce what after all was the only thing they were aiming at producing, namely, their commodities at the cheapest possible price. Should anybody think he had taken unfair advantage of their kindness in asking him to speak, he would just remind them of that old and very true saying: That when a man got to the age when he was no longer able to set bad examples he invariably turned round and started to teach others. (Applause.) He gave them the toast, coupling with it the name of their esteemed President, Mr. Russell.

Pig-Iron to Analysis.

The President, in responding, was very relieved to find that Mr. Fox did not expect him to tell them what was wrong with the pig-iron industry. They were, as big users of fuel, all glad to hear what had been imparted to those who went to the Stanton Ironworks concerning the remarkable results which had been achieved there as regards fuel consumption. Mr. Wilson, the foundry manager of Stanton, gave a Paper at Sheffield last year on that subject, and it might interest them to know that Mr. Wilson had told them that afternoon that he gave that Paper a year too soon, because he had achieved very much more since than he had achieved when he read the Paper. He threw that out as a suggestion to the London Branch as being a suitable subject for one of next year's Papers. With regard to Mr. Fox's remarks as to the use of the cheap Derbyshire iron as against the use of certain special irons, they might spend a whole session discussing that subject; but if Mr. Fox could persuade his fellow iron-masters to supply them with pig-iron of a known silicon content, instead of calling it No. 1, No. 2, No. 3, and No. 4 brand, he might find that the demand for his iron went up very considerably at small expense to himself. (Applause.)

If any Institute should hold an annual function, it should be the Institute of British Foundrymen. Their members were scattered all over Great Britain. They had a branch in every important industrial area, and each of those branches was complete with its own President, Council, membership list, and funds, and was quite capable of conducting its own affairs. Unless the representatives of the various Branches met together in conference once every year, there was grave risk of the programmes of the branches becoming parochial and narrow, thus hindering very much the development of the intellectual welfare of their members, which was the first item in their constitution.

Improved Quality Castings Available.

Considerable progress had been made in the production of castings of all sorts and sizes during the last few years. There had been a particularly big spurt owing to the more rigid specifications introduced during the war, but he was sure that they would all agree that there was still a very wide field for the use of castings—he was not referring necessarily to iron or to steel, but to non-ferrous and white metal castings—if only they could get a higher quality still. He believed the most likely way in which that could be developed was by the exchange and interchange of ideas in their branch meetings and at their annual conventions. Every section of the industry, whether it was grey-iron manufacture, steel manufacture, or non-ferrous manufacture, had its own peculiar problems, some of them being particularly applicable to the whole industry and not to a section only. He was thinking, for instance, of the non-ferrous industry, which had to use a considerable proportion of very expensive metals. If the world demand reached anything like normal, or increased in a normal way, it appeared to him that they would be forced to seek for substitutes for some of these metals. In addition to the problems peculiar to each section of the industry, there were many problems which were common to all of them, which could certainly be solved at meetings of the Branches or of the Convention. The Institute could claim that much of the success that had already been achieved in improving the quality and quantity production of castings of all grades was due to the work it had already done.

He was very pleased that next year he was to be followed by a President so well known in the non-ferrous world. (Applause.) Their membership predominated in grey-iron founders, and there was a risk of their getting too much of the various irons, including malleable iron, in their programmes, so tending to overlook the important non-ferrous section. With a President coming along who was almost entirely devoted to the non-ferrous section, he thought that side would receive more attention in the future.

A National Examination.

In his presidential address, he had referred to the development with which the Institute was faced. The first of these was the reframing of the membership classification in such a way that the recipient of an award would be recognised as a fully-qualified foundryman capable of taking his place in any executive position in a foundry. The second point was the organisation of national examinations. Considerable progress had been made (rather more than some members realised), in organising foundry classes up and down the country, but as these schools of technology could only organise their own local examinations, prepare their own papers, and issue their own awards and certificates, naturally those certificates had very little value outside their own areas. The Council, in its wisdom, had decided that it was to the benefit of the Institute to try and organise a national examination under some central body.

One question which had come much to the fore in connection with papers at the Institute was the question of costing. In discussing foundry costing, he was fully aware that they were on the border line of their constitution, but one could not have a healthy industry unless their members knew what their products cost to produce. (Hear, hear.) He had been surprised, in discussing that matter with members up and down the country, at the infinite variety of costing methods. The surprising thing was, that no matter what method was used one only reached the same result. Well might the foundryman of the old school say: "Let me have a look at the pattern, and I will tell you what the selling price is." Unfortunately, many of them were not so gifted, with disastrous results to the trade. He hoped that that question, after being thoroughly ventilated in the Institute, would be taken up by the employers' associations (which were the appropriate body to handle it), and would be followed right through to a successful issue.

Inquests.

Frequently, they were advised that one of the most profitable ways in which a foundryman could educate himself was to hold an inquest upon his scrap castings. He was very much struck with one instance of peculiar verdicts given by a coroner in his reminiscences. A body had been found in an open field, and there was considerable doubt whether the death could be ascribed to homicide or lightning. The jury returned a verdict of "death due to a visitation of God under suspicious circumstances"—(laughter)—which was rather an apt verdict for many of the inquests they had to hold. Some of these inquests were held owing to the fact that the moulder employed on a particular job had suffered from syncopated heart. He had been told by specialists that "syncopated heart" was caused by erratic movements from "bar to bar." (Laughter.)

He felt that whatever honour he had received in being appointed as President was due more to his Branch than to himself, and he was very proud of his Branch. They were so keen on that Conference that they had got their programme ready before the Sheffield Conference had begun, and it might interest them to know that their programme of fifteen months' ago was being rigidly adhered to with the omission of one detail only.

Organising Officials Thanked.

They must excuse him making one or two special references to members of his Branch. The Council had been wonderfully enthusiastic, and he hoped that the arrangements they had made had been found to be adequate. (Applause.) The team spirit shown by the Council had been really amazing. Out of a Council of 24, they had never less than 18 or 20 present, and they had held a meeting every month for months. There were four members of the Council to whom he must particularly refer. The first was their old friend, Mr. Pemberton. Mr. Pemberton was the senior elected member on the Institute Council. He was the first secretary of the East Midland Branch, which was formed after the Leicester Branch had been absorbed by the East Midlands Branch. It was his own fault that, years ago, he was not their President, but he (Mr. Russell) was particularly glad he was not, because they had him as Branch President when the Conference was meeting in Leicester. He had been a driving force in programme-building, and they could not satisfy him until they had everything cut and dried. The next member he must refer to was their old friend, Mr. Bunting, who had acted so well as the hon. convention secretary. He was the senior branch secretary in the Institute. He had held that office far longer than any other branch secretary in the area. (Loud applause.) Mr. Bunting was a glutton for work. No matter how much work was given him, it would be carried through promptly and efficiently. He also desired to mention Mr. H. H. Moore, whom he looked upon as the stalwart of their Branch. (Applause.) In the East Midland area they had not always been able to get along swimmingly, but whenever Mr. Moore came into the committee room with his confident smile and cheery optimism, all their difficulties vanished. Mr. Moore was amazingly justified in his confidence, but they had not felt like that until they had Mr. Moore's assistance behind them. As Treasurer of the Convention Fund, his success had really been astonishing. Lastly, he must refer to his brother, Philip, who had been his right-hand man throughout the Convention. They would realise that, in the East Midland

Area, with their President and Secretary living in Derby, there had been an enormous amount of detailed work to do in Leicester. His brother started to collect all the material for the handbook, and other printed matter. He had been putting in full time for the last ten days in detail work in connection with the Convention. (Applause.)

He would conclude with a simile borrowed from the Rev. "Dick" Sheppard in his wireless address which was broadcast the other evening. After addressing his listeners, he ended up by saying that he was fully aware that many of them could be considered as buttresses of the Church, but not pillars. He then explained that a buttress always remained outside. They had a big fabric to build up in the Institute of British Foundrymen, but he was quite sure that their members would not be buttresses, but would be prepared to be pillars. (Applause.)

The Guests.

Mr. Sydney A. Gimson (Past-President) desired to use the word "Guests" in rather a bigger sense than intended on the toast list, and say what a great delight it had been to him to meet the whole of the foundry people in Leicester for the Conference. It had been a great delight to him that the Conference had been once more held in Leicester. In the old days he was then occupying the position so capably and so charmingly filled that evening by his old friend, Mr. Russell. (Applause.) One missed the faces of many good friends; but they had the satisfaction of feeling that those they missed did very good work in the time they were with them, and were not unprepared to pass on. He found as one got older that it was a good deal more difficult to remember things and faces accurately, and he was a bit like the old lady in the poem which ran:—

"There was an old lady of Sheen
Whose musical ear was not keen,
She said: It is odd
That I cannot tell God,
Save the weasel from Pop goes the Queen."

(Loud laughter.) He wondered sometimes what was the origin of such toasts as these, and he was a little bit inclined to think it was keeping in existence one of the old superstitions of pouring out libations to the gods, so that one could get their friendly interest. They were all delighted to see their guests, and to wish to do them honour. He had prepared something to say about Sir Henry Fowler, and they were all very sorry indeed that he was not there, as he would have been a most distinguished guest. They all knew the great work he had done on the Midland Railway. They were very proud in that part of the country of the Midland Railway. Among the guests there were two Mayors, the Mayor of Leicester and the Mayor of Loughborough, the latter of whom was to reply to that toast. Mayors were very important people. They were the first citizens of their towns during their year of office; and naturally every Mayor was jealous for the reputation of his own town. Therefore, he had to tread warily: if he said too much about Loughborough he would be in trouble with the Mayor of Leicester, so he would only say that the towns of Leicester and Loughborough were the two most important towns in the country. (Laughter.) They were very much indebted to Loughborough in that Loughborough possessed one of the finest Schools of Engineering in the country. It was experimental to a great extent, but he believed it was succeeding. In industry or in education, or whatever it was, if one were not prepared to try big and important experiments, one would never get on. It was the most important experiment attempted in Loughborough, and was being watched by the engineering industry all over the country with the greatest possible interest. Leicester wanted a head of its School of Technology, so it went and secured the head of the Loughborough Engineering Department; but he was sure Loughborough did not mind the loss, because the head of their Technical School, Dr. Schofield, was one of the finest engineers engaged in the education of the country. (Applause.) He need not say very much about Mr. Moss himself. Everybody knew the Mosses of Loughborough, and how much they were respected in that town. He might mention that it had been pressed upon him to tell them how much they were indebted for the very kind way in which they had been received at the Stanton Works, and he hoped that message would be carried there by Mr. Fox. The second speaker to reply to the toast was their good friend, Mr. Charles Benion, who was the Chairman of the British United Shoe Machinery Company, Limited. Since he came there and joined the little firm of Merry & Benion up to the day when he became head of the great Corporation, the British United Shoe Machinery Company, Mr. Benion had always served Leicester well, and had now become one of its most respected and important citizens.

A Basic Industry.

THE MAYOR OF LOUGHBOROUGH (COUNCILLOR ALAN MOSS), in responding, was very pleased to thank the Institute because he had partaken of their hospitality and had spent a delightful evening on one previous occasion. He thanked them not only on behalf of the guests, but particularly on his own behalf for that special evening at the same time as he thanked them for their hospitality that night. He was of the impression as a layman that the public generally knew too little of the working of the Institute of Foundrymen generally. With some wonderful and beautiful exceptions, their products did not appear to the layman as what one might call the finished article, but the fact remained that they were the foundation of all mechanical devices and contrivances, which was tantamount to saying that they were of vital import to everything they used, wore, ate or travelled with. In that mechanical age everything was done by machines, and the foundryman's work was the foundation of all these machines. Like other foundations, they were not very often seen and very seldom talked about, unless they failed. But the fact still remained that they were of paramount importance. In thanking the Institute on behalf of the guests for its hospitality he thought it was their duty also to thank them for the work they were doing in their Institute. They had placed before them high ideals in maintaining and improving the high standard of excellence which England held in all mechanical work. He wished them every prosperity and every encouragement in their work.

Engineers Should Buy, Not Make, Castings.

MR. CHARLES BENION, J.P., said it gave him great pleasure to have that unexpected opportunity of replying to the toast. He was not a foundryman, but he had been one many years ago. He might say that he was a friend of foundrymen, because he was a large consumer of castings. Perhaps he might be forgiven if he touched upon a somewhat personal matter in expressing the deep pleasure it gave him at seeing Mr. Russell in the position he was occupying as President. Before Mr. Russell was born he was associated with his father and his grandfather in business, so that he could say he knew the whole family. That experience had led him to appreciate the progress which ironfounding in that city had made; and the admirable manner in which Mr. Russell had studied his profession, and the way he had presided over the conference on that occasion. (Applause.) So long as the Institute of British Foundrymen could command presidents as earnest as Mr. Russell was, they would do good work. Much had been said about the development in ironfounding. No one knew that development better than he did. He was in charge of a foundry when he was 23; and he had further experience in acquiring and managing another foundry, only to give it up because he came to the conclusion that a man could not attend to a foundry unless he made it his sole study in business. If a man were capable of running a foundry he was capable of running it for himself and not for anybody else. He did not believe in a man running an engineering shop and running a foundry. He came to that decision many years ago. He had had many tempting offers to go into the foundry business again but he had always declined them. It was better and cheaper for them to get the experience of those who had made a life-long study of the problem than to go into the foundry business themselves. Years ago in designing a machine one made the castings as simple as possible: but to-day, with the idea of making the working as simple as possible, every engineer was making the castings as complicated as possible. He must say the foundrymen had risen to the occasion. There were castings being made to-day which engineers and foundrymen in his early days would never have thought could have been made, and it was all for the benefit of the industry. (Applause.)

During the evening the lady members and visitors were each presented by the Convention Committee with a pair of Leicester-made silk stockings as a souvenir of the occasion.

The proceedings concluded with a dance, which lasted until the small hours of the morning.

THURSDAY, JUNE 14.

Morning Session.

Mr. S. H. Russell, President, in the chair.

The PRESIDENT announced that one of their oldest members in years, Mr. W. J. Tarrant, had unfortunately died most suddenly at his hotel. Though personally he had not the privilege of knowing Mr. Tarrant, he was very well-known to many of the members, and was a regular attender at their recent Conferences. As soon as they had heard this sad news, their Secretary, Mr. Makemson, went to the hotel and expressed his sympathy with the relatives. The Secretary and, in the absence of the Branch-President, their Branch Secretary, would represent the Institute when the body was removed to the station to be taken home. Mr. Tarrant had reached the age of 82 years; and, although it was very depressing for his relatives, perhaps it was rather a happy way for a man of that age to pass away whilst still in business.

At the request of the President, the company stood for a moment in silence.

The following Papers were then read and discussed:—

"Steel Castings for Severe Service," by John Howe Hall. Presented on behalf of the American Foundrymen's Association.

"The Cohesibility of Rammed Sand," by Ivan Lamoureux. Presented on behalf of the Association Technique de Fonderie de Belgique.

"Iron Foundry Costings," by W. R. Wintle, F.C.W.A.

A special session on non-ferrous metallurgy was held in another room under the chairmanship of Mr. Wesley Lambert, Senior Vice-President.

The following Paper was read and discussed:—
"Aluminium Casting Alloys," by George Mortimer.

Contributions to Hospitality Fund.

At the close of the discussion the chairman called upon Mr. H. H. Moore, the treasurer of the Hospitality Fund.

Mr. H. H. Moore appreciated the opportunity being given to him of thanking on behalf of the Convention Committee all those who had so kindly assisted to provide the necessary funds to enable them to offer what he hoped would have been found at least up to the usual standard of entertainment and general hospitality which prevailed at their annual Conferences. The Conference provided an excellent meeting-place for all engaged in the foundry industry and foundry trade and commerce. It was gratifying to know that the supply sections were still ready to help them, and in that way they benefited the industry in what might be regarded as a matter of mutual interest. But the major portion of their hospitality fund contributions came, as must always be the case, from the larger firms situated in the district where the Convention was taking place. Those firms had contributed very liberally. In the East Midlands district they were somewhat unfortunate, because, although they embraced Leicester, Derby and Loughborough, they had not the same number of large firms as existed in an area like Glasgow or Sheffield. But it was gratifying for them to know that the large firms interested had come along in a very generous manner. (Applause.) The contributions to the Hospitality Fund had reached over £500. (Applause.)

He might refer to the future Hospitality Fund, because it was not only their own that they had to think about, but there were future Conventions. Probably their members would note that they could be of the very greatest assistance to the Hospitality Committees in beginning propaganda fairly early. On behalf of the Convention Committee he thanked all the contributors to the Hospitality Fund, and he hoped all the members would realise the value of the Convention in the interests of the industry as a whole. (Applause.)

During the morning the ladies visited the historical buildings and other places of interest in the city of Leicester.

Upon the close of the Conference Session the whole of the members and their ladies journeyed by special train to Derby. The train was composed of dining-car stock, and luncheon was served *en route*.

On arrival at Derby the ladies were conveyed by motor coaches to the works of the Royal Crown Derby Porcelain Company, Limited. After inspecting the works, they proceeded to the "King's Café," where they were entertained to tea by the Convention Committee.

The members also spent the afternoon in works visits. A large party visited the works of Ley's Malleable Castings Company, Limited. Another group inspected the L.M.S. Railway works, where they were received by the Chief Mechanical Engineer, Sir Henry Fowler, whilst a third visited the works of Messrs. Rolls Royce, Limited. At all three works the members were entertained to tea and the thanks of the Institute were addressed to the respective directors and staffs.

On the conclusion of the works visits the party rejoined the special train at Derby and proceeded to Matlock Bath, where they were entertained to dinner by the Convention Committee at the Grand Pavilion. Mr. H. Pemberton, chairman of the East Midlands Section, presided.

Mr. F. J. Cook, Past-President of the Institute, expressed the thanks of the members and their ladies to the East Midlands Branch for their hospitality. He said the members of the Institute were very grateful to the East Midlands Branch for organising the Conference, and he paid a tribute to the Conference Committee, particularly their President and Secretary for the excellent arrangements which they had made and for the wonderful organisation which they had established for the management of the Conference.

Mr. J. T. Goodwin, ex-President, seconded the vote of thanks, and referred to the value of social intercourse which was such an important feature of the Conference.

Mr. F. P. Wilson, the newly-elected Vice-President, supported the resolution in a witty speech.

Mr. H. Pemberton replied on behalf of the Conference officers and Committee, and expressed the pleasure which the East Midlands Branch had in entertaining the Conference. He paid a tribute to the work of his fellow officers, and said that whatever success had attended their efforts was due to the spirit of goodwill and co-operation which prevailed.

A musical programme was provided by Miss Constance Pemberton (daughter of the Chairman), Miss Vera Burrows, Messrs. Ronald Gates, Peter Moore and Fred. Todd. The party then returned by special train to Leicester.

FRIDAY, JUNE 15.

The morning of Friday, June 15, was given over to works visits, mostly in Loughborough, although a party of ladies visited the works of Liberty Shoes, Leicester, before proceeding to Loughborough. The remainder of the members and ladies travelled to Loughborough by motor coach, where the ladies visited the works of Zenobia, Limited, perfume manufacturers.

Most of the male members of the party took part in visiting works of Messrs. Herbert Morris, Limited, the well-known manufacturers of cranes and lifting machinery. Another group visited the works of Messrs. John Taylor & Company, Limited, the world famous bell founders, and witnessed one of the oldest branches of the foundrymen's art. Another group visited the Loughborough College, which has established a reputation for the practical and technical training of engineers.

At the conclusion of the various visits the party assembled near the Loughborough Carillon, where a recital was given by Mr. W. E. Jordon, the Borough Carillonneur.

The whole of the members and ladies were afterwards entertained to lunch by Messrs. Herbert Morris, Limited, in the Town Hall. The guests included His Worship the Mayor of Loughborough, and also representatives of the various works which had been visited during the morning.

Mr. W. H. Purnell, J.P., vice-chairman of Messrs. Herbert Morris, Limited, presided, and after the toast of "The King" had been honoured, the Chairman welcomed the guests in the name of his Company. He pointed out that although a small town, Loughborough was industrially very progressive, and it had a very large variety of industries for a town of its size. Loughborough was also an important agricultural centre, and was well known as an important hunting headquarters.

Mr. S. H. Russell, President of the Institute, expressed the thanks of the members and ladies to the directors of Herbert Morris, Limited, for their hospitality. He also thanked the directors of the various works which had been visited by the members and ladies.

Mr. H. H. Moore, Past-President of the East Midlands Branch and a director of Herbert Morris, Ltd., replied on behalf of his firm, and said that they were both delighted and honoured at the opportunity of entertaining the members and ladies of the Institute.

Upon the conclusion of the luncheon the party rejoined the motor coaches in which they had journeyed from Leicester and drove through the beautiful Charnwood Forest district. A halt was made at the charming cottage of Mr. S. A. Gimson, a Past-President, where tea was provided. The visit which members paid to Mr. Gimson's cottage some years ago still remains a pleasant memory with the older members of the Institute, many of whom were glad to again have the opportunity of renewing old memories. The cottage was designed by Mr. Gimson's brother, and stands in an elevated, though sheltered, position which commands a very wide view for many miles around.

Later in the afternoon the members returned to Leicester, and the official programme of the Convention was thus brought to a close.

PAPERS PRESENTED AT LEICESTER CONFERENCE.

MALLEABLE CASTINGS.

By W. T. Evans and A. E. Peace.

The preparation of a Paper on malleable castings to be put before European foundrymen presents difficulties which would not arise if only one class of material had to be considered such as is the only product of malleable foundries in America, viz., black-heart, in the production of which the authors are now actively engaged. Having had experience of both European and American malleable it is hoped to give some idea of the general production of the two varieties, as many features are common to both.

It is generally known that Reaumur commenced the production of malleable castings in Europe somewhere about the year 1722, and that Boyden, who emigrated to America from England, in attempting to make Reaumur malleable with the American pig-irons, obtained results, about 1826, which were the foundation of the present black-heart process. The manufacture of castings by this latter process has been in operation in Europe for over 50 years, using chiefly American pig-irons, but now excellent results are being obtained by the use of all British irons, which can be bought to as close specifications as American irons provided the pig-iron is ordered in large enough quantities to enable manufacturers successfully to control the burden of their blast furnaces.

There can be no doubt that malleable castings in Europe have been something of a bogey to the engineer, owing to a non-uniformity of quality, and in particular with regard to indifferent machinability which under present-day conditions is a most serious matter, owing to the expense of mass production tooling operations. This fact is emphasised by the latest B.E.S.A. specification for malleable which includes a clause to cover a minimum speed for machining.

In this Paper the authors will endeavour to convince engineers and users of malleable castings that a reliable product from both blackheart and white-heart varieties can be, and is being, produced by the application of correct methods.

Basic Differences.

The authors feel that before going into the details of manufacture it would be advisable briefly to describe the two classes of material.

White-heart, or Reaumur, castings are usually produced from metal melted in the cupola or crucible from pig-irons of a grey mottled or white fracture, the mixture of which, with the necessary scrap, is controlled to obtain castings of a white fracture free from graphite. The following gives some indication of the analysis of the castings as poured:—T.C., 3.0 to 3.5; Si, 0.5 to 0.8; Mn, 0.10 to 0.40; S, 0.20 to 0.45; and P, 0.06 per cent.

The melting of metal for black-heart castings is carried out in acid open hearth, air furnace or electric furnace, the use of the cupola not being satisfactory. Pig-irons used are of grey hematite quality, which, together with scrap and sprue, are blended to produce a graphite-free casting, similar in fracture to the white-heart casting, but of a very different composition, as is shown by the following analysis:—T.C., 2.30 to 2.70; Si, 0.7 to 1.00; Mn, 0.25 to 0.35; S, 0.03 to 0.08; and P, 0.20 (max.) per cent. It will be noticed that the chief differences in composition of the two malleables are the lower T.C. in the black-heart and the much higher percentage of sulphur in the white-heart material. Reference will be made to these in greater detail later.

White-heart castings are annealed in an oxidising packing of hematite ores at a temperature of approximately 980 deg. C., for a period at the highest temperature of about 100 hrs. Black-heart annealing is carried out with no oxidising packing at a temperature of around 850 deg. for a period of 60 hrs.

The common names of the two varieties have arisen from the appearance of the fractures of the annealed castings. The white-heart when fractured shows a dull grey skin merging rather sharply into a bright crystalline centre or core. The skin consists of decarburised iron which progressively increases in combined-carbon content to the centre where the structure is a pearlitic matrix with, frequently, free cementite, and some free carbon nodules. (See micro-graphs, Figs. 1 and 2.)

The fracture of annealed black-heart is uniformly black throughout except for a slightly lighter appearance on the extreme edge. The structure is ferrite with rounded nodules of free carbon (temper carbon) distributed throughout. (Fig. 3.)

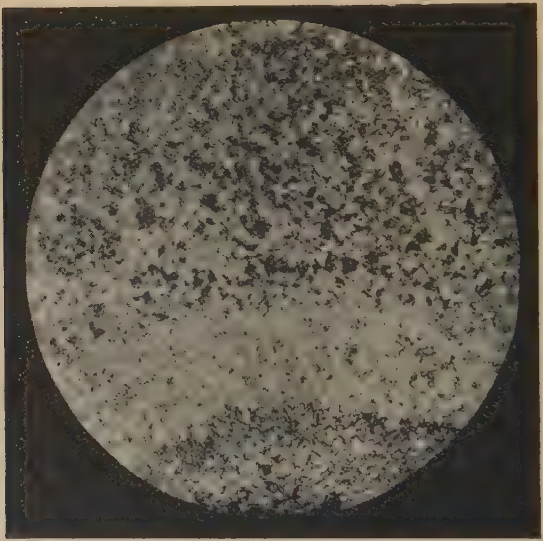


FIG. 1.—RIM OF ANNEALED WHITE-HEART. ETCHED × 50.

The B.E.S.A. specifications Nos. 309 and 310 indicate the physical properties of the two types, and a portion is here abstracted:—

Ultimate Tensile Strength (minimum)	White-heart 20 tons.	Black-heart 20 tons.
Elongation in 2 in. (minimum)	5 per cent.	7½ per cent.
Bend. Cold. Round 1 in. rad. (minimum).	45 degrees.	90 degrees.
Machineability. Approx.	90 ft. per min.	90 ft. per min.

MANUFACTURE.

Air Furnace Melting for Black-heart.

The air furnaces used have capacities ranging from 5 to 30 tons and typical furnaces are illustrated in Figs. 4 and 5. The furnaces are lined with good-quality firebricks which have to stand temperatures around 1,600 deg. C., and resist the action of a slightly oxidising slag. Aluminous bricks excel in withstanding the high temperatures and erosion, but exhibit unwelcome spalling propensities, owing to the rapid cooling of the furnace when a heat is taken off and another one charged. Table 1 shows the life of various bricks in the walls.

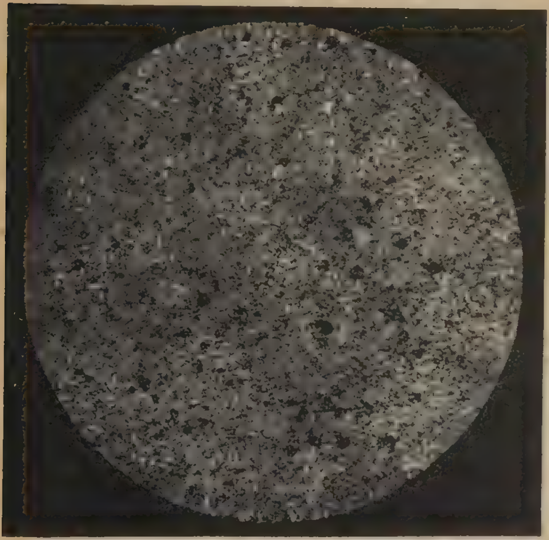


Fig. 2.—Centre of Annealed White-Heart. Etched × 50.

Silica sand is generally used for making the bottom of the bath, but firebrick bottoms have been adopted in some cases with success. The advantage of the latter type of bottom is the saving of fuel required to frit or burn a bottom in. A sand bottom will last about 8 or 9 heats, whereas a brick bottom with care may run to

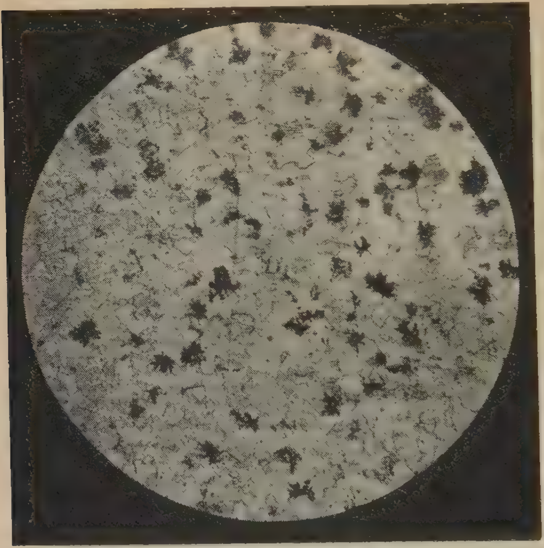


FIG. 3.—ANNEALED BLACK-HEART. ETCHED × 50.

TABLE I.—*Life of Various Refractories in Air Furnace Walls Using Pulverised Fuel.*

Analysis.	Firebrick Good Quality.	Aluminous Brick.
SiO_2	63.90	47.62
TiO_2	1.12	3.80
Fe_2O_3	2.20	1.34
Al_2O_3	29.73	44.58
MgO	0.46	0.25
CaO	0.88	1.10
Alkalies	1.71	1.31
Melting Point ..	1700°C.	1780°C.
Life Average Number of Heats.	13	17

5 or 6 times this life, which means a direct saving of 80 per cent. of the fuel and time for fritting.

In laying a brick-bottom, joints about $\frac{3}{8}$-in. wide are left between the bricks, and a space of 2 in. or so, where the bricks meet the side walls, is rammed up with dry grog, prepared from used firebricks, which is also run in loosely between the joints. This procedure is sufficient to prevent the bottom cambering when expansion of the bricks takes place.

TABLE II.—*Life of Refractories in Air Furnace Bungs Using Pulverised Fuel.*

Analysis.	Good Quality Fire Brick.	Aluminous Brick.	Sillimanite Brick.
SiO_2	59.40	49.34	36.35
TiO_2	0.79	2.00	2.13
Fe_2O_3	4.97	2.10	2.34
Al_2O_3	32.78	43.56	58.02
MgO	0.96	0.45	0.06
CaO	0.60	1.01	0.60
Alkalies	0.50	1.54	0.50
Melting Point deg. C.	1680	1740	1800
Life Average Number of Heats	27	30	25
Causes of Failure	Erosion	Chiefly Spalling.	Spalling.

The roof of the furnace is made of loose arches braced by cast-iron or steel frames, which can be adjusted to take care of the expansion and contraction of the bricks. The requirements of firebricks for these arches or bungs are ability to withstand the cutting action of the flame at high temperatures and the rapid change in temperature occasioned after tapping a heat and recharging. The life of the bungs is around 27 heats, but those which are continually being removed for charging the heat give a much shorter life, owing to the disturbance of the joints and to the rough usage. Table II shows the bung life obtained from various qualities of bricks.

Conditions Influencing the Life of Refractories.

One of the chief factors which determines the life of refractories is the velocity of the flame passing through the furnace, and with furnaces

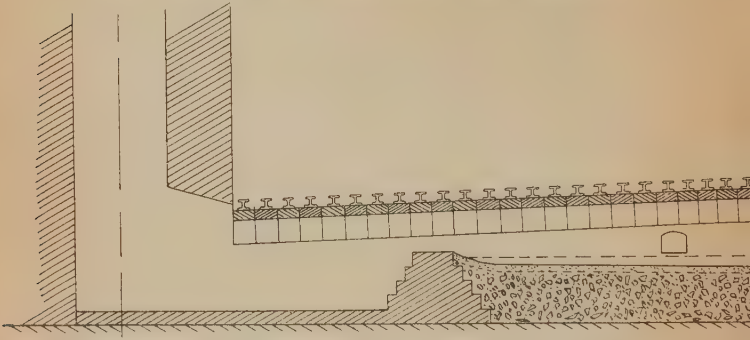


FIG. 4.—PULVERISED-FUEL FIRED AIR FURNA

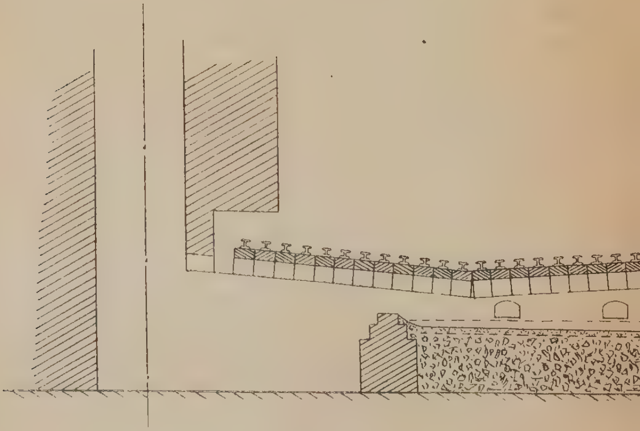
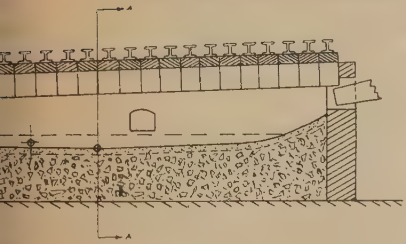
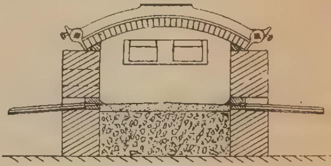


FIG. 5.—HAND-FIRED AIR FURNACE. 6 T

working on pulverised fuel the secondary air should not be admitted to the furnace at a pressure above 2 oz. Burners and pipe lines are designed of sufficient area to supply the correct volume of air at this low pressure. Dry coal and low velocity are the first essentials for the successful application of pulverised coal.

With hand-fired furnaces air is admitted below the fire grate in such quantities as partially to burn the coal with a distillation of the volatile

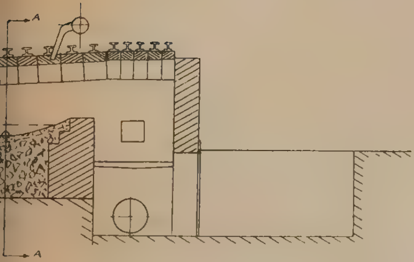


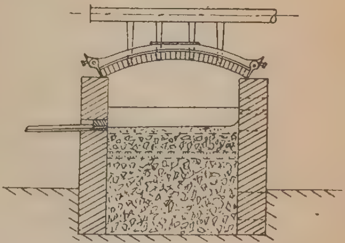


— Section AA. —

Tons Capacity.

products, and pass into the furnace what is virtually a low-grade producer gas. The secondary air, which is admitted through tuyeres in the roof, effects combustion of this gas in the furnace. The pressure of the primary air under the firebars must be so regulated as not to blow any of the small coal over the front bridge on to the bath. This happening, usually termed "throwing





— Section AA. —

ACITY.

ashes " increases the carbon content of the bath and is often caused by using friable coals.

The Bath.

It will be observed from Figs. 4 and 5 that the roof is built with a straight taper from burners or firebox to bridge. The bath of metal may be from 5 to 9 in. in depth at the deepest part (lower taphole), depending on the capacity of the furnace: too deep a bath lengthens the time required to obtain the necessary casting temperature. Tapholes are usually put in at two levels, the lower to drain the bath and the higher one to take off the hottest metal first. These holes are better made with a special brick, such as is shown in Fig. 6. Frozen tapholes can be easily opened out with an oxygen torch; that is, a length of iron piping $\frac{1}{2}$ in. dia. coupled to an oxygen cylinder, gas being delivered at about 30 lbs. pressure.

Charging Operations and Fuel Ratios.

When charging a furnace two or three bungs are removed at the front and at the back of the furnace. The scrap and sprue are first charged and levelled down, following with the pig-iron and steel scrap; the bungs are replaced and luted up. With hand-fired furnaces using a hard bituminous coal a ratio of iron to fuel of 2.25 may be obtained with good practice; this should be associated with a melting speed of 30 mins. per ton. When melting with pulverised coal, ratios of 2.50 to 1 may be obtained under good conditions, and the melting speed is improved up to 20 mins. per ton. Much better times and ratios than these are obtained in American practice, 3.0 to 1 being common, and the authors have seen heats made with a 4.0 to 1 ratio. There seems no doubt that these excellent figures are obtained by reason of more easily dried fuel. The composition of suitable American and English coals is compared in Table III.

In connection with fuel ratios it should be borne in mind that they vary considerably with the size of the heats which can be melted, which factor is determined by the class of castings being produced, as one day a single large heat may be run and another day two smaller heats may be necessary to clear the floor space.

Test Plugs.

With pulverised-fuel furnaces, the charge is not touched for from two to three hours, by which time the flame will have levelled it down. The removal of slag from the molten bath assists in raising the temperature of the metal into which the furnaceman pulls down any piles of unmelted iron. Complete fusion is then quickly obtained, and slagging proceeds until the surface of molten metal is practically clear. If the temperature of the bath is judged to be high enough, tests are taken with a sampling ladle. The authors have adopted the practice of casting test plugs in cores made from ordinary oil-sand mixtures. This has been standardised to overcome the variation of speed of solidification and further cooling, which is seriously affected by using green sand, which may be either dry or, on the other hand, very wet. It will be seen from Fig. 7 that a notch in the lower half of the plug is made, which ensures a fracture in the same position every time. After a test plug is poured it is left in the core until set. It is then cooled off by inverting it and immersing the upper end in a trough of running water arranged to give a standard depth of immersion of approximately 2 in. Thus by placing the bars vertically the portion eventually to be fractured is not unduly chilled by contact with the water.

The taking of tests is proceeded with at 15 min. intervals until the fracture of a slaked test is judged to be evidence that the bath has attained the desired composition for tapping. With good melting practice two or three tests will meet the requirements, and by this time the bath will be hot enough for casting. The illustrations comprising Fig. 8 show fractures of test plugs, with analyses appended, which are representative of the progress of a heat.

This method of tapping by fracture a border line iron which is only permitted a small range of chemical variation may seem, in the light of present-day cast-iron criticism, somewhat crude, but when it is considered that out of some 12,000

TABLE III.—*Analysis of Coals Suitable for Malleable Air Furnaces.*

		Suitable for Hand Firing.				Suitable for Pulverised Firing.			
		English.		American.		English.		American.	
		1	2	1	2	1	2	1	2
Moisture.		7.06	5.96	0.62	1.10	8.20	9.04	1.53	1.35
Proximate Analysis on Dried Sample	Volatile Matter	31.73	32.46	35.63	33.95	33.18	35.69	32.02	33.64
	Fixed Carbon	63.40	59.53	58.32	60.68	59.83	58.72	60.58	58.26
	Ash	4.85	8.06	5.43	4.27	6.99	5.59	7.40	8.10
Sulphur		0.35	0.84	0.70	0.45	0.84	0.62	0.61	0.61
Calorific Value B.T.U.s. ..		13,900	11,580	13,902	14,276	13,301	13,755	13,856	14,027

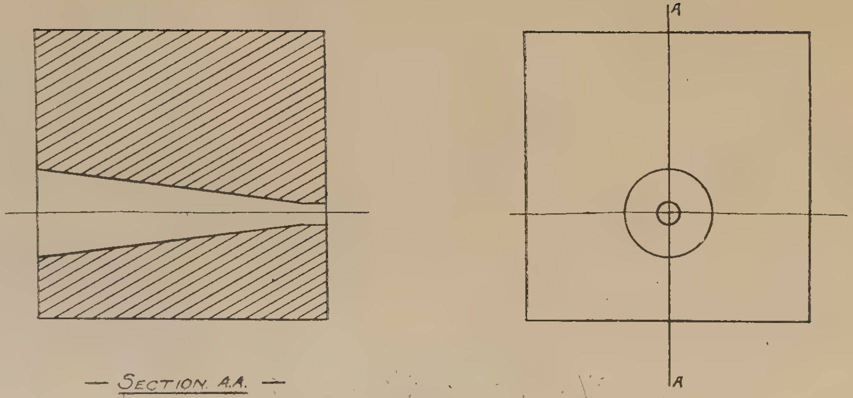


FIG. 6.—TAPPING HOLE BLOCK. SCALE 1/6.

heats poured, with an aggregate tonnage of approximately 100,000 tons, only six failed to produce satisfactory material for annealing, one has to admit that this practice is perhaps equal to the more scientific methods so much advocated.

Recording Data.

Regularly recording the details of furnace working is very useful. Fig. 9 (pp. 80-81) shows the recorded data on one month's operation of a furnace.

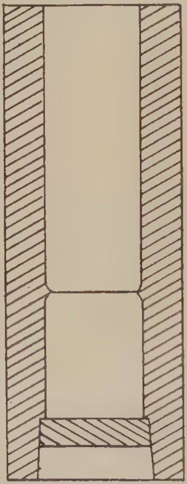


Fig. 7.—Section Through Test Piece Core. Scale 1/3.

As S and P are subject to little variation, only TC, Si and Mn are entered. It will be seen that the information summarised includes weight of charge, time of melting, weight of fuel used and melting ratio, additions made, number of tests taken, important repairs and the furnaceman's check number.

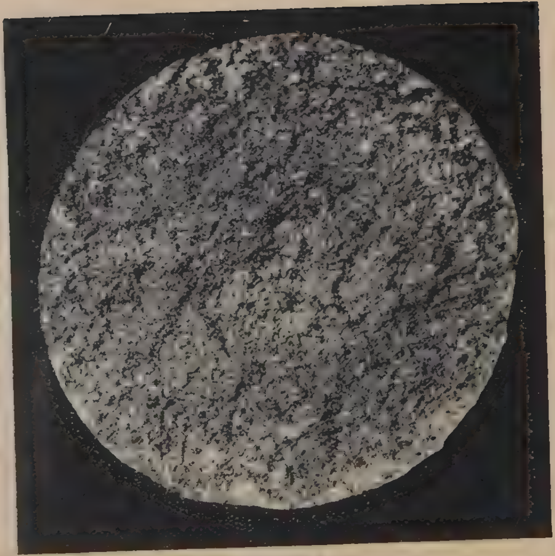
Adjustments to Composition.

The number of tests, and the appearance of the fractures, together with the analytical and other data from the particular mixture and previous heats on the furnace in question, enable those in charge of the melting operations to decide whether any additions of carbon, silicon or manganese are necessary. These are added to the bath in the form of crushed, hard coke, 45 per cent. ferro-silicon and 80 per cent. ferro-manganese, and are put up in standard quantities equal to definite percentage additions per ton of melt.

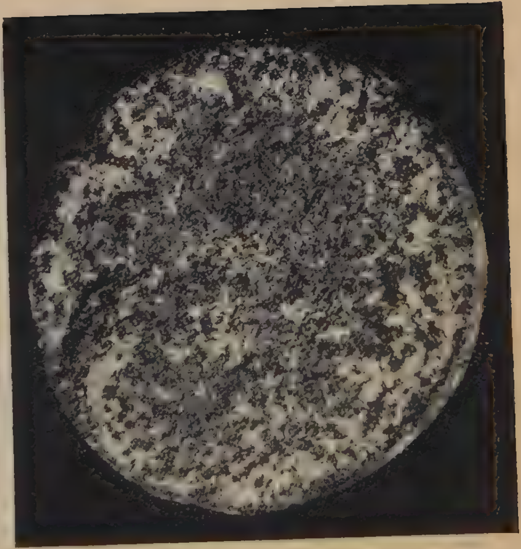
An ideal composition for the hard iron is TC, 2.35; Si, 0.85; Mn, 0.28; S, 0.05, and P, 0.20 per cent. (max.), and mixtures are used and operated to obtain this analysis. The loss of carbon, silicon and manganese on melting varies with each furnace and with other factors, such as slight alterations occasioned by repairs. It will therefore be seen that separate mixtures should be made for each furnace and frequently adjusted to take care of the slight changes in melting loss. It is sometimes advisable to change the mixture, apart altogether from analytical considerations, as the fluidity and life of the iron may not be all that is desired.

Losses Sustained.

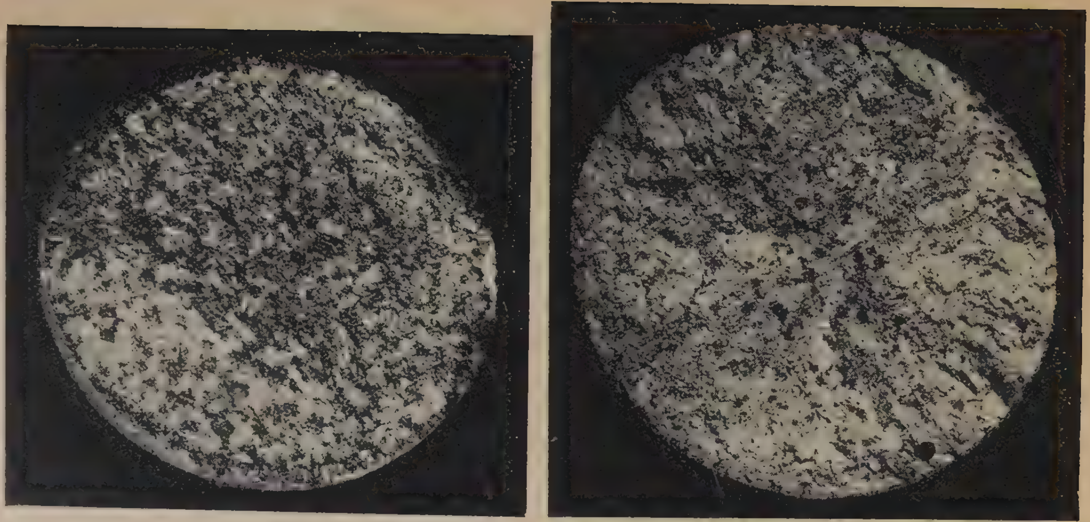
Typical losses are TC 0.80, Si 0.35, and Mn 0.20 per cent. Phosphorus is unaffected in melting, but there may be a slight increase in sulphur content. This is of the order of 0.005 per cent. The composition of the charge on a furnace with such melting losses will therefore be TC, 3.15; Si, 1.20; Mn, 0.48; S. .045 per cent., and P, 0.20 per cent. (max.). In malleable foundries the amount of shop scrap, *i.e.*, the necessary feeders and runners and scrap castings, is in the neighbourhood of 45 per cent. of the metal melted, and this is the controlling feature in the computation of the mixture. The composition of this scrap is that of the hard iron cited previously. Assuming that there is sufficient to make 45 per cent. of the charge the average composition of the raw materials, *i.e.*, pig-iron and steel, must be TC, 3.80; Si, 1.49; Mn, 0.65; S, 0.04, and P, 0.20 per cent. (max.). This necessitates the use of hematite pig-irons. It is convenient for the basis irons to be of two grades as regards Si content, *e.g.*, 1.0 to 1.40 per cent., and 1.40 to 1.80 per cent., the other elements being the same as the average required. It is useful to have other pig-irons for use in small quantities for adjustment of mixtures, with a similar Si content,



(a)



(b)



(c) (d)

FIGS. 8A, B, C, D.—FRACTURES OF TEST PLUGS, ILLUSTRATING PROGRESS OF AIR FURNACE HEAT BEFORE TAPPING.

but with a Mn in one case, low, say 0.25 per cent., and in the other case, high, say 1.25 per cent.

Low grade ferro-silicon, with a Si content of about 10 per cent., is also sometimes charged in small quantities. It might be mentioned here that the chromium content of all raw materials must be low, as it has a very serious effect on graphitisation, as referred to later.

Properties of the Hard Iron.

Fig. 10 shows a micrograph of the hard iron produced. It will be seen that it consists of approximately 75 per cent. pearlite and 25 per cent. free cementite; the dendritic structure is usual for all white irons. A remarkable feature of this low-carbon white iron is its tensile strength, which is about 30 tons per sq. in. It is interesting to record that it is fairly easily machined, and has a Scleroscope number of 45 to 48, equal to a Brinell of 300 to 350. It will withstand considerable rough usage, as it is not nearly so brittle as the ordinary higher-carbon white irons. It has been used with success for castings which would otherwise have to be cast in chilled moulds. This material is regularly being machined to fine limits, and small additions of manganese, in the form of 80 per cent. ferro-manganese, to the ladle when pouring improve its machining qualities, with little change in the analysis.

Melting for White-heart.

The melting of iron for white-heart is usually carried out in the cupola. This is by far the quickest and cheapest melting medium to produce malleable castings. Although this would seem to show considerable saving compared with air furnace practice, the composition of the metal cannot be controlled to such fine limits.

Broadly speaking, any cupola suitable for melting grey iron will be satisfactory for malleable. As the metal required must be low in Si and P, and is always high in S, it will be readily seen that it must be highly superheated to obtain the life necessary successfully to pour the light classes of castings made. It is essential to use good coke, and charge somewhat larger quantities than is usual in cupola practice. The cost of fuel per ton

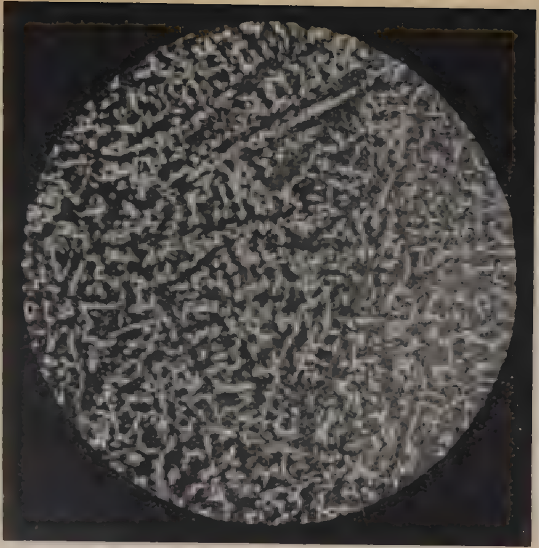


Fig. 10.—Unannealed Black-Heart. Etched × 50.

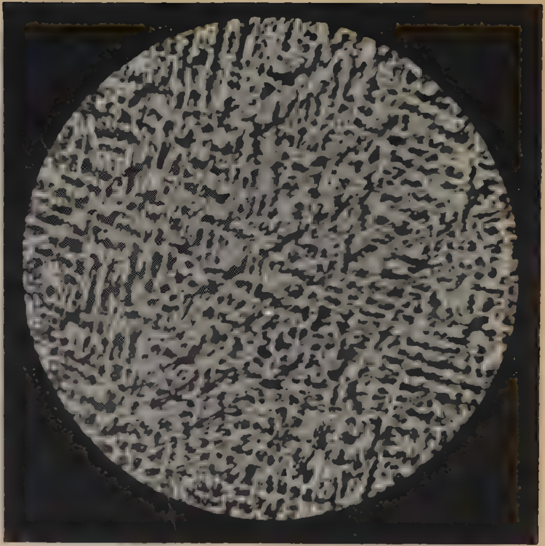


Fig. 11.—Unannealed White-Heart. Etched × 50.

of good castings is very much more than is the case with grey iron, as in addition to the poorer fuel ratio, the percentage of feeders and runners is from two to three times greater.

Apart from the greater fuel consumption, there does not appear to be unanimity on the details of cupola working for malleable. Higher blast pressures are favoured by some, but there is no doubt that this should be governed by the diameter of the cupola and the disposition and area of the tuyeres. The essential requirement is hot, clean iron, and any practice which fulfils this with regularity may be considered good.

Use of Refined Irons.

Pig-irons are confined to hematite quality as the maximum phosphorus content permissible is 0.20 per cent. These irons are usually of the white and mottled grades, but vary considerably in composition. The following shows the range covered:—T.C., 3.00 to 3.80; Si, 0.40 to 1.20; Mn, 0.10 to .70; S, 0.15 to 0.45; and P, up to 0.10 per cent. In addition refined irons are largely used. The nature of the refinement is somewhat obscure but appears, at any rate in many cases, to consist of remelting the ordinary hematite irons in the cupola with the addition of steel in an attempt to lower the carbon content. Some refined irons are now made which have been considerably desulphurised, and when used with care these are very beneficial. The experience of many workers tends to show that the "refined" irons produce better malleable castings than the ordinary grades.

The pig is mixed with the shop scrap which, as indicated previously, is sufficient to supply about 50 per cent. of the charge. The annealed scrap is used by many founders to a slight extent, while others condemn it. It seems that with good practice small quantities can be used successfully, but the continued use of amounts above 5 per cent. of the charge produces metal with short life.

The losses on melting vary considerably with the cupola practice adopted and the pig-irons used. The total-carbon shows little change, although generally the tendency is towards a

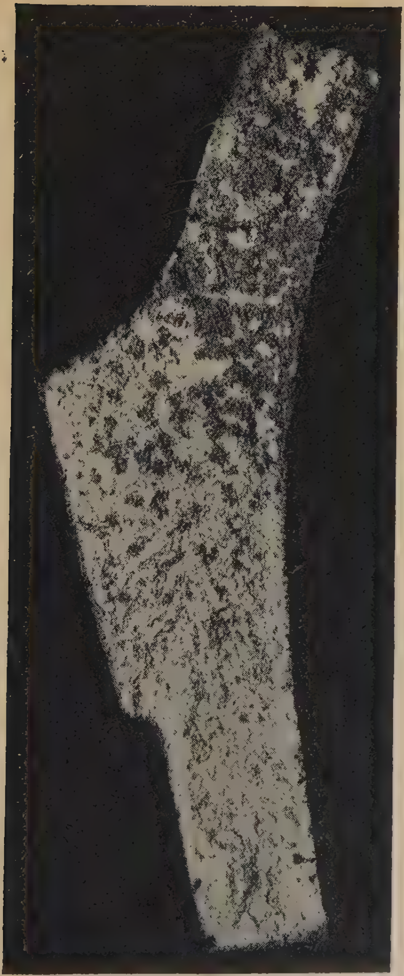


FIG. 12.—GREY TO WHITE FRACTURE IN UNANNEALED BLACK-HEART CASTING.

slight loss. The Si loss may run from 0.15 to 0.25 per cent. The manganese loss is largely dependent on the manganese and sulphur content of the charge, and there is usually very little loss, although with pig-irons of fairly high Mn. content and very hot melting, a considerable loss may be obtained, figures of 0.25 per cent. have been recorded. The gain in sulphur content depends so much upon the coke used and the temperature of melting that it is impossible to give a figure, but it may be stated that low-sulphur coke, hot melting, good fluxing, and fair manganese content in the pig-iron, favour a small sulphur pick up.

It is common practice to run two mixtures, one for heavy castings and one for light work. Usually the analysis is similar except for the Si content. Suitable compositions for both classes are :—*Heavy:* T.C., 2.9 to 3.2; Si, 0.45; Mn, 0.20; S, 0.25; and P, 0.08 per cent., and for *Light:* Si, 0.75 per cent., the other elements being similar to those used for heavy work.

Fig. 11 shows the micro structure of the hard iron from which it will be seen that there is about 40 per cent. of free cementite and 60 per cent. of pearlite. It is interesting to compare this with the lower carbon hard iron of the black-heart process.

Moulding.

The moulding of malleable castings is a fruitful source of knotty problems to the founder, some of them are common to all classes of moulding, but the majority are not met with by the founders of grey iron. Feeding, pouring, gating, etc., are very different from ordinary practice, and a casting which will present little or no difficulties in most foundries, may become almost impracticable for manufacture as a malleable casting. For this reason, purchasers of malleable will be well advised if they place before the manufacturers the drawing or design for approval before proceeding with the patterns for new work, as very often some slight change in section or design will lead to success in production.

There can be no hard and fast line for the production of satisfactory work, and only a general idea can be given, for what may seem satisfactory to-day, may from some unforeseen circumstances require changing to-morrow. That which appears here will certainly not apply in every shop.

Primarily the founder has to produce the casting from material which will satisfactorily anneal or his efforts are useless. To achieve this it is necessary to pour the moulds with irons of a low-silicon-content and in the case of black-heart with a low total-carbon content both of which shorten the freezing range. With white-heart the T.C. may be much higher, but the low silicon, together with the very much higher S. will bring about somewhat similar conditions of freezing. Therefore, there must be a high degree of superheat in the metal as poured. This high casting temperature, short freezing range, high liquid and solid contraction are a set of conditions which make the production of castings of uneven and thin sections anything but an easy proposition. But in the face of this, good, reliable, sound castings are made as will be acknowledged from the data shown of machinability to be presented later in this Paper.

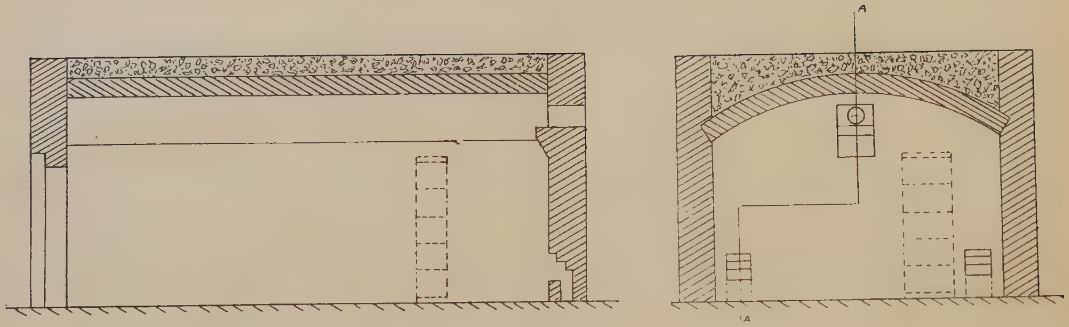
It will be seen that to overcome these special conditions, the founder cannot adopt grey-iron foundry practice of running a softer mixture for the light work, owing to the fact that an iron which would give a white fracture in sections of $\frac{3}{8}$ in. thickness, may show much free carbon in sections of 1 in. or over. It is necessary to compromise. As all castings cannot be made of one

Table IV.—*Analyses of Metal from a 12-ton heat on pulverised coal-fired air furnace taken at ten-minute intervals during running out.*

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
T.C. ..	2.46	2.42	2.38	2.33	2.30	2.28
Si ..	0.938	0.938	0.938	0.938	0.938	0.938
Mn ..	0.309	0.305	0.299	0.296	0.286	0.253

Table V.—*Analyses of Metal from a 5-ton heat on a hand-fired air furnace taken at five-minute intervals during running out.*

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
T.C. ..	2.46	2.41	2.36	2.32	2.31
Si ..	0.906	0.906	0.896	0.890	0.890
Mn ..	0.326	0.317	0.302	0.299	0.299



— SECTION A.A. —

FIG. 12A.—PULVERISED-FUEL FIRED ANNEALING OVEN.

section the practice is adopted, where possible, of pouring the light castings from the air furnace early and those of the heavier types later in the heat. With cupola melting this would be the reverse, *i.e.*, the heavy work cast first. Every advantage is taken of the changes of composition which from experience are known to occur which ever medium is used for melting, as it minimises manufacturing difficulties. Tables IV and V show changes of composition during pouring.

Generally speaking, moulds must be poured quickly, as it is necessary to fill them with liquid metal so that there is the time and temperature for the heavier parts of the castings to secure the advantage of the necessary feeders and chills. Slow pouring often causes short run and drawn castings, especially if the iron in the feeders is not hot, also it is a frequent cause of small "pin" holes appearing in the castings, the iron not being of sufficient temperature for gases to escape.

It is desirable with large castings not to admit too much iron into the mould at one particular spot, as it may so heat up the mould locally as to cause a grey or heavy mottled fracture where this has occurred. An example of this is shown in Fig. 12. Moulds should be soft-rammed consistent with the size of castings, whilst the sand should be as dry as possible with no local aggregations of red-sand. The latter together with hard-rammed and wet moulds is a prolific source of defective castings. Where trouble is found in running very thin castings, the fault may be in the use of too close a sand-mixture, and this can be remedied by the addition of sharp sands. With the use of highly superheated metal, trouble with slag inclusions is experienced, and as most of the work is cast with hand ladles the ordinary skimming methods cannot be used. These small inclusions would not be so important were it not for the after heat-treatment.

Common Defects.

Pulls, which are small fissures or cracks, often occur at changes of sections, or corners which have not enough fillet, or on the outside of circular plates. These must be avoided, and are often

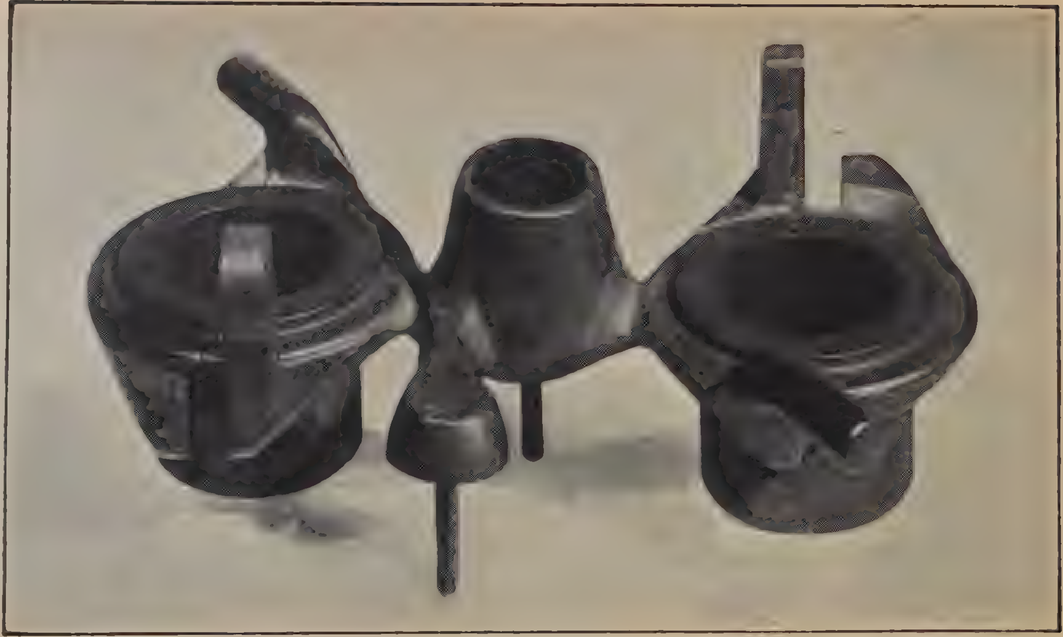


Fig 13a.—Spray of Castings, showing "Spinning" Feeder.

remedied by what in malleable foundries are termed " ties." These are thin sections of metal added across the position on the casting where the pull shows. This thin piece of metal sets sooner than the adjacent part of the casting and so takes the contraction strain. The tie is easily trimmed from the casting in the hard state. Cracks which may pass the hard-iron inspection are plainly revealed after annealing, opening up with expansion of the metal. Differentiation is made between hot cracks, or pulls, and castings accidentally cracked in the hard state, by the appearance of the surface of the fractures after annealing, the former having a rough or grained fracture and the latter a practically smooth face.

Cores should be made friable consistent with strength to withstand handling, and in many cases they must be made hollow, so that they readily collapse and allow the casting freedom for contraction. Sprays, horn-gates, spinners and sieve runners are among numerous methods of running adopted. A fairly representative selection is shown in Fig. 13.

Feeding.

Feeding is a most important feature and the proportion of runners and feeders to castings may vary from 30 to 70 per cent. by weight, according to the class of work and the method of production. In the spray moulding of light castings, the spray must be strong enough to carry the patterns and withstand the rapping, and in this method the proportion of sprue to castings is always high.

Wherever possible, top feeding should be avoided, as this is a source of dirty moulds, and wasteful of metal owing to the fact that the iron in the feeding head is open to the atmosphere, causing it to set quickly, which can only be overcome by increasing the body of metal.

The better practice is to fix the feeders on the joint of the mould. This involves no loss of pressure, and ensures the feeder remaining liquid until the casting has drawn from it. Cylindrical castings with flanges, particularly, are always better fed on the joint, in the root where the flange meets the body.

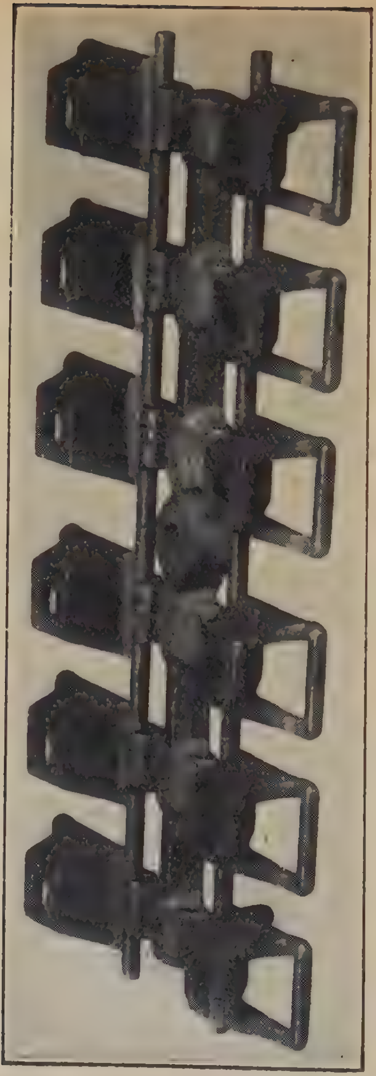


FIG. 13B.—SPRAY OF CASTINGS. NOTE THE HEAVY RUNNER.

Special attention should be given to the facing sand. This must not be too close nor too wet. The proportion of coal dust must be carefully adjusted for different classes of work. Too much coal dust will result in miss-run castings of the lighter type, owing to the large amount of gas generated and the formation of "air locks." With metal very low in carbon and highly superheated, sand may be burnt on the castings to such an extent that they cannot be readily cleaned.

To run castings successfully with large areas of thin and intricate sections, it is an advantage to preheat the moulds and close them immediately before pouring. Where moulds are made and dried to facilitate moulding, and if there are any heavy sections, it is essential that the moulds be cold before casting to avoid grey fractures.

The illustrations, Figs. 13*a* to 13*f*, are some common examples of patterns as used in malleable foundries. The first is a spray of patterns which shows plainly what is commonly called the "spinping" feeder. This is not always the best method of running castings, as it will be seen that if the mouth into the casting is larger than that where the metal enters the feeder, there is a likelihood of dirt floating into the casting. Fig. 13*b* demonstrates the excessive weight of runner which has to be employed to hold a spray of small patterns, if any length of service is to be expected. Fig. 13*c* is an illustration of a pattern for the bottom part. The metal enters through a small perforated core, the print for which is shown at the end of the runner. Fig. 13*d* is the pattern for the top part of the same mould showing feeders fixed on the joint, also ties at either end, close to the feeder mouths to eliminate the pulls which very often appear there, due to these spots being the last to solidify. Figs. 13*e* and 13*f* are two further examples of the top and bottom halves of a pattern, showing somewhat similar methods of running and feeding, together with ties, which in this case are not on the joint of the mould.

Annealing.

Both black-heart and white-heart castings can be annealed in the same design of ovens (Fig. 12*a*), which may vary in capacity from 3 to 30 tons.

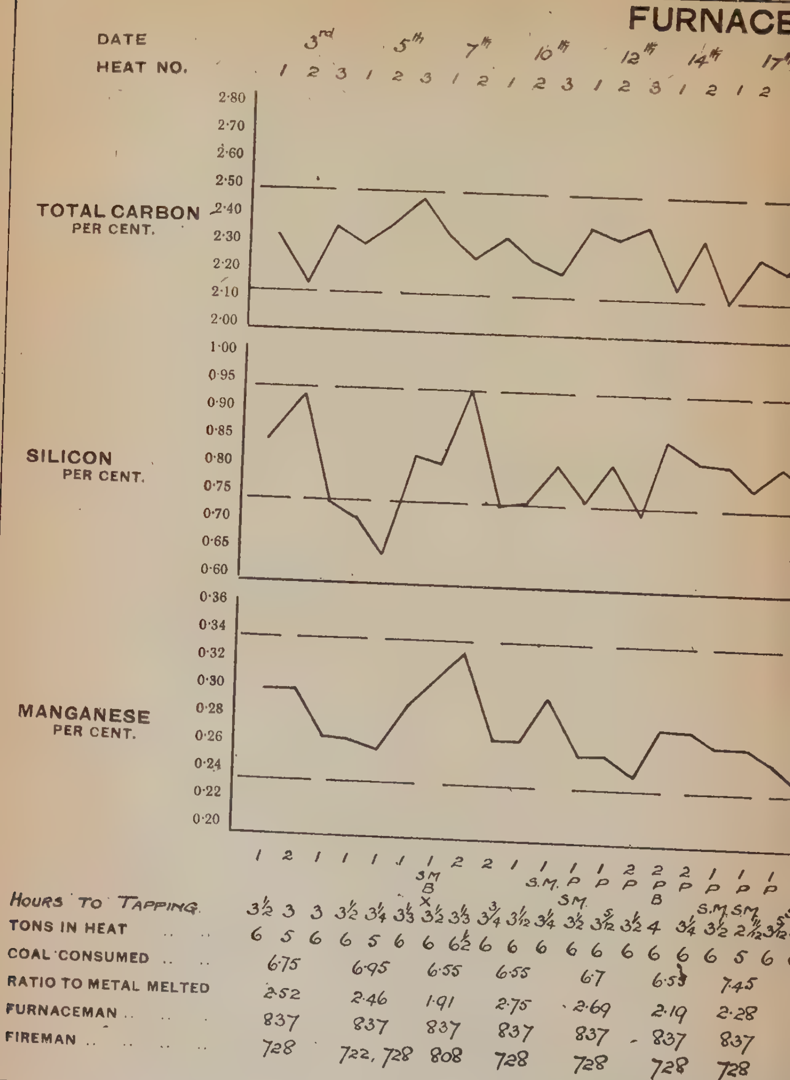
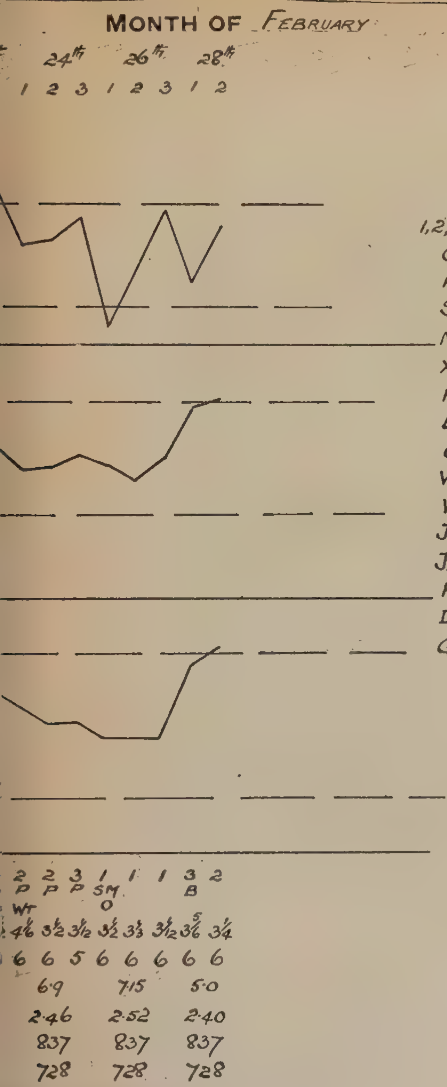

FURNACE
DATE
HEAT NO.
3rd
5th
7th
10th
12th
14th
17th
1 2 3 1 2 3 1 2 1 2 3 1 2 3 1 2 1 2
TOTAL CARBON PER CENT.
2·80
2·70
2·60
2·50
2·40
2·30
2·20
2·10
2·00
SILICON PER CENT.
1·00
0·95
0·90
0·85
0·80
0·75
0·70
0·65
0·60
MANGANESE PER CENT.
0·36
0·34
0·32
0·30
0·28
0·26
0·24
0·22
0·20
1 2 1 1 1 1 1 2 2 1 1 1 1 2 2 2 1 1 1
SM B X
S.M.
P SM
P
P
P B
P
P
P
P
S.M.
SM
HOURS TO TAPPING 3½ 3 3 3½ 3¼ 3⅓ 3½ 3⅓ 3¾ 3½ 3¼ 3½ 3 5/12 3½ 4 3¼ 3½ 2 11/12 3 5/12
TONS IN HEAT 6 5 6 6 5 6 6 6½ 6 6 6 6 6 6 6 6 6 5 6
COAL CONSUMED 6·75 6·95 6·55 6·55 6·7 6·53 7·45
RATIO TO METAL MELTED 2·52 2·46 1·91 2·75 2·69 2·19 2·28
FURNACEMAN 837 837 837 837 837 837 837
FIREMAN 728 722, 728 808 728 728 728 728

FIG. 9.—AIR FU



TING RECORD.

— KEY —

1,2,3 etc.	No of TESTS SLAKED
C	COKE ADDITION
P	FERRO SILICON PIG CHARGED
S	FERRO SILICON ADDITION
M	FERRO MANGANESE ADDITION
X	MIXTURE CHANGED
K	HEAT MARKED & SEPARATELY ANNEALED
B	NEW BOTTOM
O	NEW SLOPE BUNGS
WT	NEW WALL TAPPING SIDE
WS	NEW WALL SLAGGING SIDE
JF	NEW BRIDGE FRONT
JB	NEW BRIDGE BACK
F	NEW FIREBOX
D	FLUE DUG OUT
G	NEW BLOWING

Much saving of fuel can be effected by the use of special insulating material in the construction of the oven doors, such as diamataceous bricks. It is usual for the walls and back of the oven to be sufficiently thick, or else for the ovens to be constructed in batteries, so that there is little loss of heat incurred in this direction. The doors, however, having to be removed for each anneal are made as light as possible, and result in a very great loss of heat, unless the precaution, men-

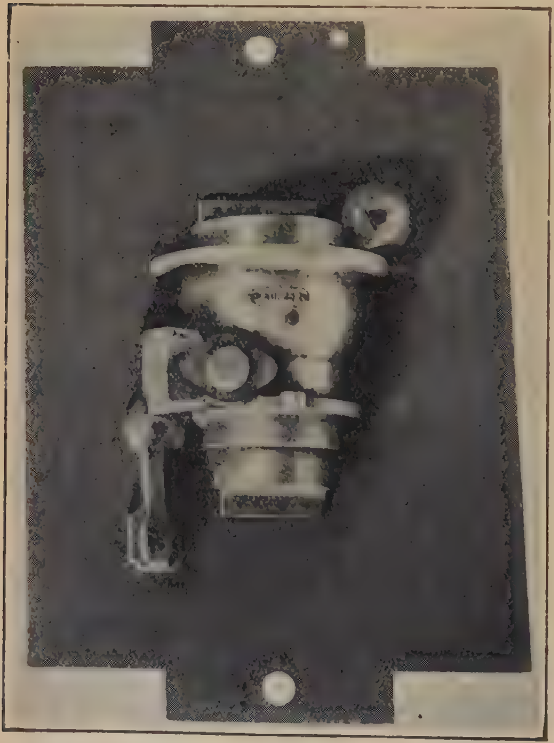


FIG. 13c.—AUTOMOBILE CASTING. NOTE THE SIEVE RUNNER.

tioned above, is taken. In addition such insulation reduces the rate of cooling, which is a very desirable feature, particularly in the case of blackheart, as will be dealt with later in a discussion

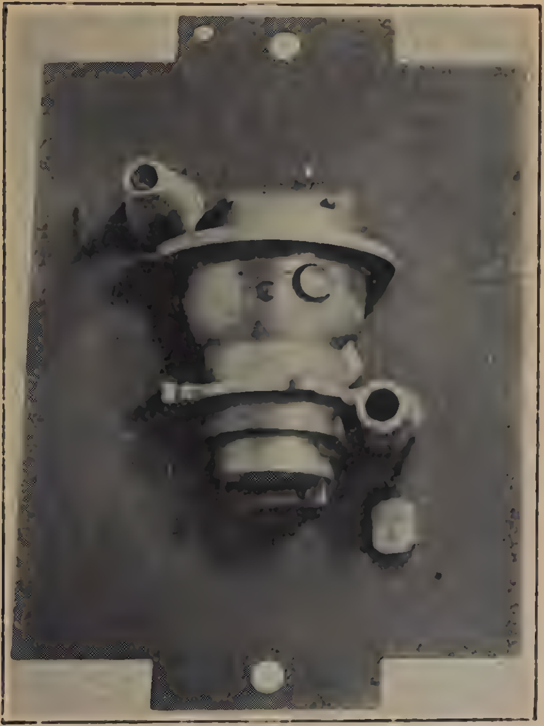


FIG. 13D.—AUTOMOBILE CASTING, SHOWING FEEDERS ON JOINT AND TIES.

on the theory of annealing. It may be pointed out that where oven doors are built up anew each time, the diamataceous bricks are too soft and firable to withstand the rough usage.

Small plants usually pack and unpack their castings inside the oven. This necessitates the oven temperature being low enough to enable men to work and handle the castings and pots before the oven can be emptied, and recharged for the next anneal. With modernised and larger plants,

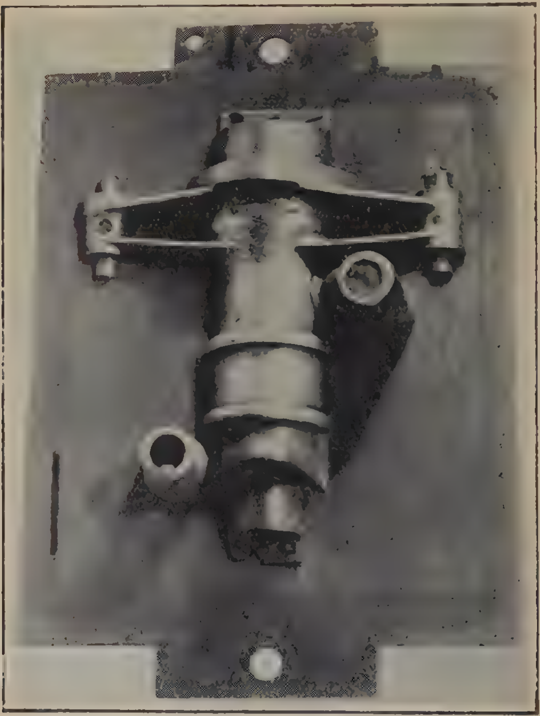


FIG. 13E. -AUTOMOBILE CASTING. NOTE THE FEEDERS ON JOINT DO NOT COME THROUGH.

the pots are packed in stacks outside the ovens, and are charged with a special truck. This shows a direct saving in time of delivery and in the fuel consumption, as it is possible to draw ovens at fairly high temperatures and recharge in a few hours.

Annealing Pans.

Annealing pans are made of white cast iron, similar in composition to the white-heart hard castings. The useful life of these pans may be prolonged by the addition of chromium from about 0.20 to 0.60 per cent., and good results have been obtained by using metal with manganese increased to about 1.25 per cent. Nickel-chrome pans, whilst giving from 5 to 10 times the life of the hematite iron pans, are prohibitive in price, as to prove economical they would be required to give some 200 times the life of the ordinary pans.

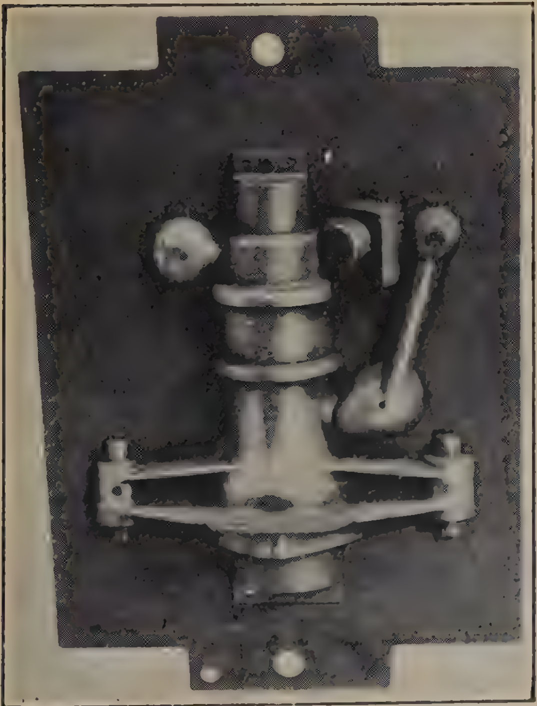


Fig. 13F.—Automobile Casting. Note the Tie on Flange.

Black-heart castings are packed in the pans with an inert material such as crushed slag, which is used to support the castings and prevent undue distortion. It also assists in protecting the castings from the oven atmosphere should a pan crack or the luting between the pans be ineffective. For castings, which by virtue of their shape and size can be closely packed without fear of warping, pans with bottoms cast in are useful. These have recessed tops which fit the bottoms of the pans so that a secure luted joint may be made. By this method packing material is discarded.

Annealing White-heart.

In white-heart annealing, the castings are packed in a similar manner, but an oxidising material is used in place of the inert material, before mentioned. This consists of hematite ores containing 70 to 90 per cent. of ferric oxide, Fe_2O_3, which during use is converted to the magnetic oxide, Fe_3O_4, and in practice generally new and old ores are mixed in the proportion of one of new to five of old. Table VI shows the analyses of some annealing ores. As this annealing process is carried out at a higher temperature than is the case with the black-heart process, the castings must be more firmly packed to prevent distortion and each casting must be in contact with the packing medium. The annealing temperature for black-heart is around 850 deg. C., and for white-heart it reaches 980 deg. C.

TABLE VI.—*Analyses of Annealing Ores.*

Description.	FeO	Fe_2O_3	Fe_3O_4	SiO_2	CaO
New Ore. Good supply	—	90.7	—	4.7	0.85
Poor Ore. Same supply	—	68.7	—	23.8	2.00
Poor Ore	—	67.8	—	11.9	7.35
Poor Ore	1.3	71.6	—	12.3	10.3
Used Annealing Ore	—	nil	79.3	20.3	0.8

Relative Annealing Costs.

It will be readily seen from these figures that in the white-heart process the consumption of coal will be greater, and the life of annealing pans shorter. The amount of coal

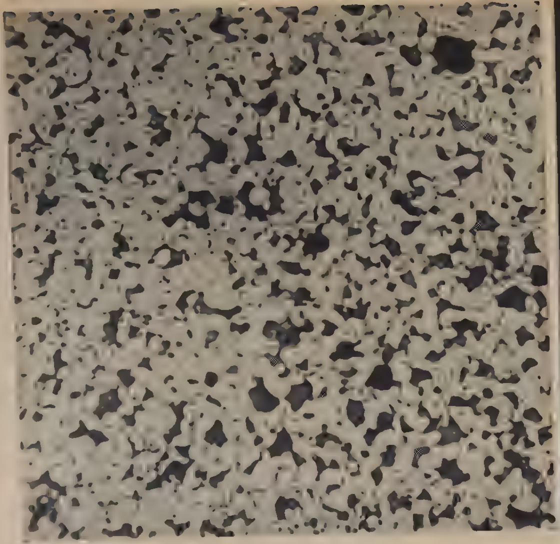


FIG. 14.—WELL ANNEALED WHITE-HEART, ETCHED × 50.

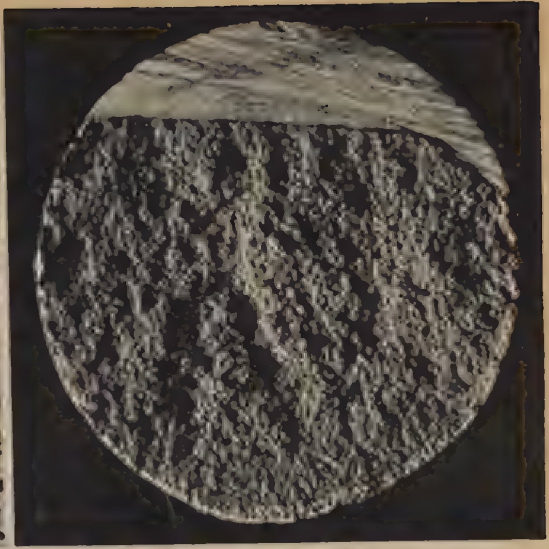


FIG. 14A.—FRACTURE OF ANNEALED 3-IN. DIAM. BLACK-HEART BLOCK

used on a pulverised coal-fired oven of 25 tons capacity in annealing black-heart is in the region of 6 cwts. per ton. With hand-firing for the same class of work the figure is about 10 cwts. per ton. No figures are available for the annealing of white-heart by pulverised fuel, but on hand-fired ovens the consumption of coal may reach 2 tons per ton of castings. Owing to the different periods of anneal adopted for various castings an accurate figure cannot be given.

The life of annealing pans in black-heart manufacture is approximately 12 heats, but in the white-heart process 7 heats is good practice. The cost of these pans is about £6 5s. per ton, and this figure must be credited with the value of the scrap pans re-sold to the makers.

THEORY OF ANNEALING.

Black-heart.

The iron to be annealed contains all its carbon in the combined form, and the structure is free cementite and pearlite (Fig. 10). This system is metastable, *i.e.*, it is stable under the temperature conditions existing, but has not reached final equilibrium. This final stable state is iron and free carbon, and is shown in Fig. 3. The condition necessary to obtain this equilibrium is the maintenance of a temperature above the lowest critical point (about 750 deg. C.) for a sufficiently long time. Above this temperature the hard iron contains austenite and cementite. In the austenite, carbon nuclei are formed, and free carbon is deposited from the surrounding austenite. The austenite maintains its carbon concentration by dissolving cementite, and this precipitation of free carbon and absorption of cementite continues until there remains a matrix of austenite and nodules of temper carbon. The austenite now graphitises, lowering its carbon content until a certain carbon concentration is reached. This concentration is definite for any given temperature, and the austenite is saturated with less carbon at lower than at higher temperatures. At just above the lower critical point the solubility of carbon is about 0.45 per cent., and below it becomes practically nil.

The time factor plays a very important part. The time required to effect equilibrium at only slightly above 750 deg. C. might be 200 hours, but the reaction is accelerated with increasing temperatures, and at 1,000 deg. C. might only take 30 hours. In practice there are very strong objections to the use of high temperatures; the most important being the very large carbon-nodules formed and the coarse ferrite structure obtained. Other obvious reasons are the extra fuel cost, greater expense on oven repairs and annealing pans, and the excessive distortion of the castings. At the lower temperatures the period required is so long as to be commercially impracticable. The temperatures usually adopted are from 820 to 870 deg. C., which are maintained for a period of 50 to 80 hours, according to the temperature chosen. When equilibrium is established at these temperatures the carbon still dissolved in the iron can be precipitated, as previously explained, by lowering the temperature to, or just below, the critical point Ar_1 (about 730 deg. C.). It is necessary to hold at this temperature for a period to complete the graphitisation of the small amount of carbon still in solution, but in practice the normal cooling rate is so slow as to allow of the reaction being completed. This rate of cooling is less than 7 deg. C. per hour. A typical record of annealing is shown in Fig. 17.

It must be mentioned that although the packing material used is inert, a small amount of decarburisation takes place. This cannot be prevented, and is no disadvantage provided it does not proceed to too great an extent.

White-heart.

Graphitisation in the annealing of white-heart takes place in a similar manner to that just described, but owing to the higher sulphur content of this type it proceeds at a very much slower rate. The speed is so slow that graphitisation would only be complete after a prohibitively long period. As previously stated, the annealing is chiefly obtained by the removal of most of the carbon by heating in contact with iron ore. The action is twofold. It consists, in the first place, of the oxidation of carbon from the surface of the castings, and secondly the migration of carbon from the centre to the skin. The mechanism of the carbon diffusion is not properly understood, but it very definitely increases with rising temperatures. Further, at higher temperatures the affinity of carbon for oxygen is greater, so that the removal of carbon is more rapid the higher the temperature. Also the removal is more rapid in the initial stages, when new ore is used. It will be appreciated from these remarks that it is possible to have a rate of oxidation at a certain temperature which is faster than the carbon diffusion at that temperature. Such a condition of affairs often exists, and this is the main reason why all new ore is unsatisfactory in use. The new ore is so vigorous in its action that it removes the carbon quicker than migration takes place, and when there is no more carbon in the surface for it to oxidise, it oxidises the iron forming a network of oxide round the ferrite grains. Such oxidation is a contributory cause to "peeling."

Commercial considerations determine that the annealing temperature shall be from 960 to 980 deg. C., and the period at this temperature approximately 100 hours. Both the temperature and time may have to be varied for different size and thickness of castings, and for very heavy sections double and even treble annealing periods are given.

Assuming the given explanation of annealing white-heart to be somewhere near the truth, it will be apparent that to remove the carbon to the same extent in the heavy parts of an uneven sectioned casting a more active oxidising medium will be required adjacent to such sections. This is one of the chief reasons why malleable castings should be made of as uniform thickness as possible. A thickened portion may add strength but not ductility. With well-annealed white-heart, the carbon is removed to such an extent that the remainder has, during the period at heat, practically all graphitised, leaving from 0.30 to 0.80 per cent. of combined carbon. This is shown in Fig. 14.

The Question of Even Sections.

From the foregoing description of the annealing processes of both types of malleable the outstanding features should be apparent. As mentioned previously, castings to be made from either

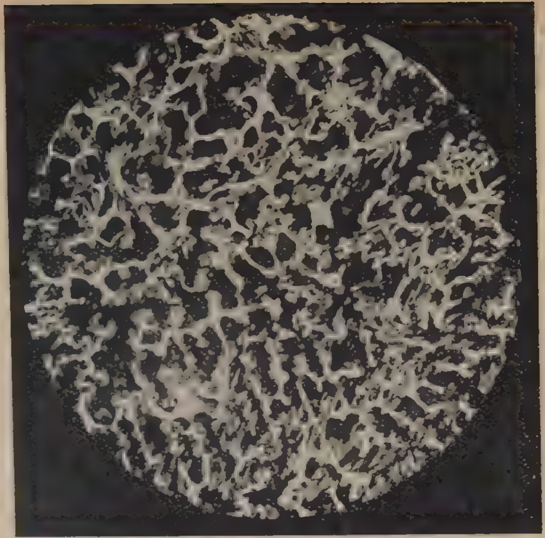


FIG. 15A.—3-IN. DIAM. BLACK-HEART BLOCK. BEFORE ANNEALING. ETCHED × 50.

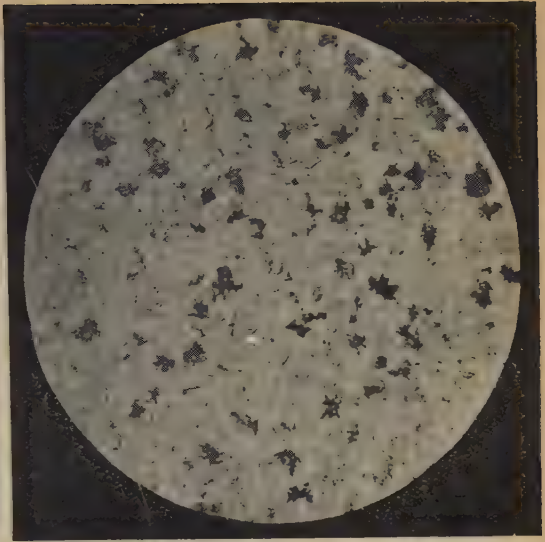


FIG. 15B.—3-IN. DIAM. BLACK-HEART BLOCK. ANNEALED. ¼-IN. FROM EDGE. ETCHED × 50.

material should be as far as possible of even sections, but for an entirely different reason in each case. In white-heart the sections should be even because of the impossibility of annealing the thicker section as successfully as the thinner one. With black-heart the question of thickness does not affect annealing. The only trouble that can accrue from a thick section is that which is common to the use of border-line irons. The mass effect so governs the rate of solidification and cooling that grey fractures are easily obtained unless special precautions are taken. The common methods adopted to safeguard against this effect are the application of chills, use of red sand, or shot-sand cores. But on heavy sections the result cannot always be achieved, as if large top feeders are necessary they may result in greyness. Grey fractures, in either type of malleable, are useless for the annealed product, as the presence of primary graphite ruins any claims to malleability There is no limit to the section which can be completely annealed in one cycle by the black-heart process, a point demonstrated by the micrographs taken from a bar of 3 in. dia., cast from a normal heat, which was annealed, once, under ordinary conditions, as shown by the chart, Fig. 17. Table VII shows the analyses from different points, and Fig. 14A shows a photograph of a fracture, Fig. 15 the micrographs. It will be seen from the latter that there is no combined carbon apparent remaining in any portion of the bars, and that the only difference in structure between the edge and the centre is the slightly larger carbon-nodules and size of ferrite grains, which has affected the quality, as shown by the physical tests in Table VIII. It should be clearly understood that the authors do not advocate 3 in. sections, but are desirous of proving that black-heart of such section can be completely annealed by the ordinary methods.

Illustrations are shown in Fig. 16 and analyses in Table IX of a 2½-in. dia. bar made in white-heart which has had one anneal and has had no special treatment. It will be seen from the amount of free cementite which is present practically right through the sample that the annealing has penetrated a very short distance only. Such material is quite strong but possesses little

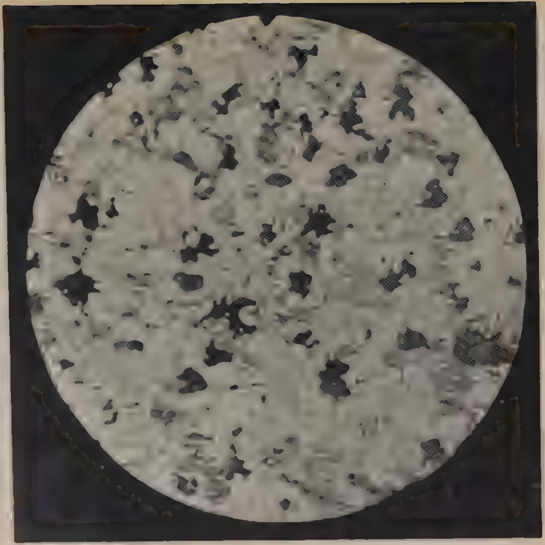


FIG. 15C.—3-IN. DIAM. BLACK-HEART BLOCK. ANNEALED. $\frac{3}{4}$-IN. FROM EDGE. ETCHED × 50.

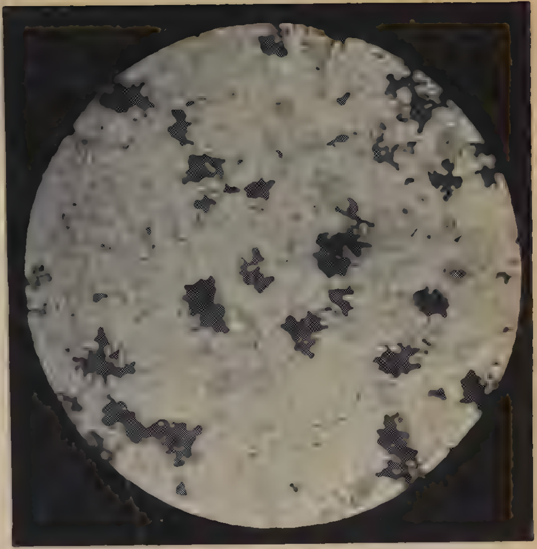


FIG. 15D.—3-IN. DIAM. BLACK-HEART BLOCK. ANNEALED. CENTRE. ETCHED × 50.

TABLE VII.—*Analyses of the Hard and Annealed 3 in. Diam. Black-Heart Block.*

	T.C.	Gr. C.	C.C.	Si.	Mn.	S.	P.	Cr.
Hard Iron.	2.33	nil.	2.33	0.848	0.258	0.036	0.097	0.006
Annealed ¼ in. from edge ..	2.20	2.15	0.05	0.894	0.277	0.050	0.106	0.006
Annealed ¾ in. from edge ..	2.25	2.19	0.06	0.892	0.277	0.052	0.104	0.006
Centre	2.29	2.23	0.06	0.894	0.274	0.052	0.105	0.006

ductility, and, except in the skin, is not readily machined. It would be impossible to cut test bars from this specimen which would fulfil the B.E.S.A. white-heart specification. It will be seen from this example that white-heart castings should be made of minimum section.

Table VIII.—*Physical Properties of Bars Cut from 3 in. Diam. Black-Heart Block.*

	M. S. Tons per Sq. In.	Elong. on 2 in. per cent.
Bar cut from edge ..	23.45	13.5
Bar cut from centre ..	20.35	10.5

It may be of value here to quote from a paper, "Some Experiences with Malleable Cast Iron,"† by H. Field. Speaking of white-heart, Field says: "There are upwards limits of section which cannot be successfully malleablised. Heavy castings 4 or 5 in. thick can be repeatedly annealed, so that the true malleablising penetrates for a distance of 1 in. or so, and the whole casting is thus rendered exceedingly strong, but in the author's experience there always remains over 2 per cent. of carbon at any depth greater than 1½ in., and under these circumstances the interior metal. although soft to a drill, would, cut out into test bar form, show only very low extension and bend properties. Such castings find extensive use in engineering construction, but it should be clearly realised that for true malleable iron, to give 45 deg. bend or 5 per cent. elongation, a section of ¾ in. represents the practical maximum."

Pyrometry

It can be stated quite definitely that unless some form of temperature measurement is adopted in the annealing operation good malleable cannot be made with regularity and certainty. Although optical and radiation pyrometers can be used, they need a certain amount of skill and understanding to be of value. Apart from the personal element in the case of the optical instrument, they both give erratic results unless focussed on a clear oven, flame and smoke making any readings worthless. The only type of pyrometry that can be wholeheartedly commended is the recording thermocouple. The couple should be immersed in an annealing pot with the castings, otherwise it simply records the temperature of the oven atmosphere, and the pots lag behind this to such an extent as to make it impossible to tell when the castings are up at heat. The couples may be made of platinum-rhodium, chromel-alumel or iron-constantan. The platinum-rhodium couple has practically an indefinite life, but the initial cost is high, and furthermore the electro-motive-force generated is very small. For example, at 900 deg. C., it is 9.2 milli-volts, whereas with chromel-alumel it is 37.0 m.v., and iron-constantan 52.0 m.v. The iron-constantan couple is useless for white-heart annealing, as its working limit is below 900 deg. C., and even at temperatures of 800 to 850 deg. the life is not very good. It will not withstand oxidising conditions, and this combined with other factors make it undesirable for malleable work. The chromel-alumel has a working life up to 1,300 deg. C., and gives very good service at around 900 deg. C. A reducing atmosphere is, however, fatal to it, as also to the platinum-rhodium.

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† Proceedings, I.B.F., vol. xx., page 407 *et seq.*

It is necessary to protect the couples with a sheath, and nickel-chrome alloys give the best service, particularly if it is further protected from the sulphurous and reducing gases by an outer sheath of iron which is cheap and readily renewable.

The recorders may be either of the galvanometer or potentiometer type. The galvanometer type is simple and gives good results, but the effect of the resistance in the leads must be taken care of, either by a high internal-resistance in the instrument, or by carefully bringing up the external resistance to a definite figure for which the instrument has been calibrated. The potentiometer recorders do not use the current generated by the couple for actuating any mechanism but simply balance it with a standard E.M.F., which is brought down by resistances. In this type the resistance of the leads has no effect on the

TABLE IX.—*Analyses of the Hard and Annealed 2½ in. Diam. White-Heart Block.*

	T.C.	Gr.C.	C.C.	Si.	Mn.	S.	P.	Cr.
Hard Iron.	2.72	nil.	2.72	0.834	0.204	0.256	0.075	0.020
Annealed ¼ in. from edge ..	2.42	1.40	1.00	0.834	0.198	0.325	0.071	0.022
Annealed ¾ in. from edge ..	2.57	1.59	0.98	0.834	0.207	0.312	0.071	0.022
Centre	2.64	1.60	1.04	0.834	0.215	0.349	0.069	0.023

accuracy which is an outstanding advantage. The mechanism of the potentiometer recorder is much more complicated than that of the galvanometer type, but it is possible to make all parts of the potentiometer more robust, and the authors have a preference for this type.

The pyrometric practice which has given the greatest success in the authors' experience is here described. One chromel-alumel couple is immersed in a pot at the front of the oven and one in a similar position at the back. The height chosen is one-third of the total height of the pots.

These couples are connected to indicators at the back of the ovens conveniently situated for the fireman's use. The indicators are equipped with selector switches and the fireman is required to record the temperatures on an oven sheet at frequent intervals. The couples are further connected through the indicators to remote recording potentiometers which give a continuous record of the couples and serve as a check on the fireman's operation. The chart shown in Fig. 17 was obtained by this system and it will be noted that the back and front have been maintained at almost even temperatures.

THE EFFECT OF THE COMMON ELEMENTS ON BLACK-HEART MALLEABLE.

Carbon.

The carbon content in well-annealed black-heart chiefly determines its strength and ductility. Since the structure is a ferrite matrix with carbon nodules dispersed throughout, the strength and ductility of the metal is that of the ferrite less the weakening effect of the free carbon. For example, good malleable with 2.80 per cent. or more carbon will not yield above 18 or 19 tons tensile strength nor give more than about 8 per cent. elongation. With a 2.00 per cent. carbon, tensile strengths of 30 tons associated with over 30 per cent. elongation have been obtained. Generally speaking carbon contents below 2.20 present casting difficulties due to the higher freezing point and shorter life of the molten metal which very much outweigh the increased physical properties. The higher carbon material will anneal more readily, but the silicon must be varied inversely to obtain a graphite-free, hard-iron, which neutralises the benefit which might be obtained.

Silicon.

The silicon is governed, as just indicated, by the carbon content. Within the narrow range of carbon permissible in good quality material the silicon may run from 0.75 per cent. with the higher carbons of, say, 2.50 per cent. up to 1.00 per cent. with carbons of 2.20 per cent. Increased silicon favours graphitisation, but its usefulness in this direction is limited by the fact that there must be no graphitisation in the hard iron.

Sulphur.

Sulphur has such a strong restraining effect on graphitisation that in a material which relies upon complete graphitisation for its useful properties, the sulphur must be kept as low as possible. The practice of increasing the manganese content to neutralise the effect of the sulphur cannot be carried beyond certain limits on account of the effect of the manganese as explained later.

Manganese.

The manganese must be present in sufficient quantity to neutralise whatever quantity of sulphur is present. The amount is not, however, the theoretical requirement to form manganese sulphide, *i.e.*, 1.72 times the sulphur content, but is in excess of this. Actual practice has established that the excess required increases with the sulphur content. With 0.04 per cent. sulphur the excess required is in the neighbourhood of 0.20 per cent. If the excess is more than 0.25 per cent. the manganese retards graphitisation, a feature which has been taken advantage of to produce castings for certain purposes as explained later, under the heading of "Picture Frame" material.

Phosphorus.

This element appears to have no effect until in excess of about 0.20 per cent., above which it is not completely soluble in the ferrite and is detrimental to the physical properties of the annealed product. It may be that the higher limit of phosphorus assists to overcome running difficulties.

Chromium.

Chromium definitely retards annealing even in small amounts of the order of 0.01 per cent.

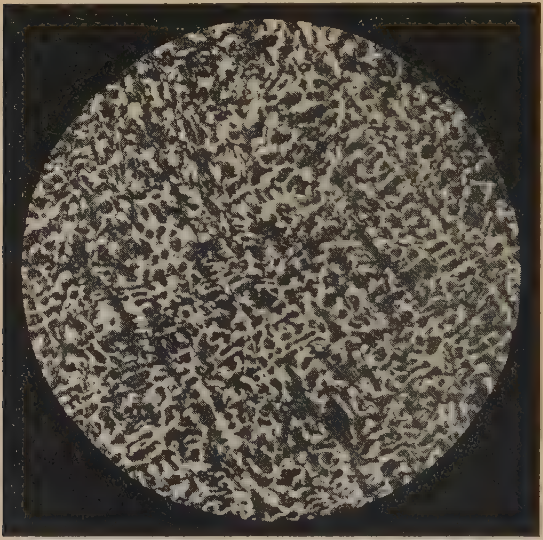


Fig. 16a.—2½-in. diam. White-Heart Block, before Annealing. Etched × 50.

Most pig-irons contain chromium in quantities up to 0.10 per cent., so that care must be taken in the choice of pig-irons.

THE EFFECT OF THE COMMON ELEMENTS ON WHITE-HEART MALLEABLE.

Carbon.

High-carbon content is prejudicial to the annealing of white-heart, as it favours graphitisation and consequently decreases the extent of decarburisation. Whilst low-carbons might be advantageous, the production of such iron in the cupola is difficult. Experience shows that carbon from 2.8 to 3.1 per cent. gives the best results.

Silicon.

With silicon-contents below 0.40 per cent. it is almost impossible to anneal the hard iron satisfactorily. Silicon around 1.0 per cent, increases the extent of graphitisation on annealing, and is opposed to the removal of carbon on account of this. As with black-heart, the content has to be varied inversely with the carbon in order to produce a graphite-free casting. With the desirable carbon contents indicated above silicon from 0.50 to 0.80 per cent. will be found suitable for most purposes.

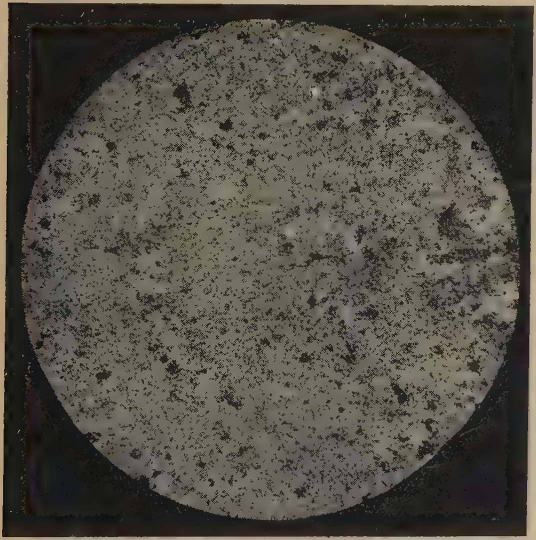


FIG. 16B.—2½-IN. DIAM. WHITE-HEART BLOCK. ANNEALED. ¼-IN. FROM EDGE. ETCHED × 50.

Sulphur.

This element is no doubt the controlling factor in the production of white-heart. Its effect on graphitisation is so well known as to need no explanation. It is the one element which makes the essential difference between the two types of malleable.. If the sulphur-content is below 0.10 per cent. graphitisation will take place in preference to decarburisation and the result is a weak iron, little better than grey iron, and is in fact very similar to the result of a high-silicon content.

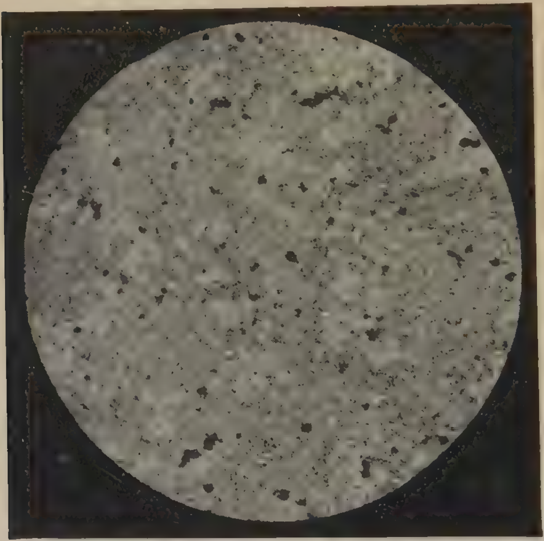


FIG. 16C.—2½-IN. DIAM. WHITE-HEART BLOCK. ANNEALED. ¾-IN. FROM EDGE. ETCHED × 50.

Sulphur above 0.45 per cent. prevents practicable annealing. Reasonable sulphur contents to produce good annealed castings are from 0.20 to 0.30 per cent.

Manganese.

From the foregoing remarks on sulphur content, it will be realised that the manganese must be low enough to allow the sulphur to exert its restraining influence on graphitisation. Yet it must not be so low as to permit the sulphur to prevent the dissociation of the carbide and so prohibit the removal of carbon by oxidation from the ore. It has been found by experience that the

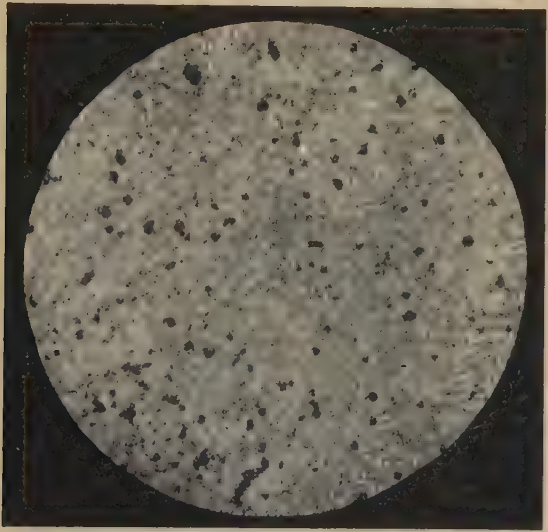


FIG. 16D.—2½-IN. DIAM. WHITE-HEART BLOCK. ANNEALED. CENTRE. ETCHED × 50.

atomic ratio of 1.72 times the sulphur gives the best conditions.

Phosphorus.

The effect of this element is as previously given in reference to black-heart.

Chromium.

Higher chromium is permissible in white-heart than in black-heart, as its stabilising effect upon the carbide is not so detrimental and up to a certain point is beneficial. Quantities above 0.20 per cent. however appear to reduce the rate of decarburisation seriously.

Table X.—*Physical Properties of Black-Heart Malleable Tensile Bars* 0.564 (9-16 *in.*) *Dia. Bend Bars* 1 *in.* × $\frac{3}{8}$ *in.*

Description.	M. S. Tons per sq. in.	E. per cent. on 2 in.	Bend. Degs.
Average of 100 Consecutive Heats	24.80	19.9	175
Bar with Highest Tensile Strength	27.00	19.0	180
Bar with Lowest Tensile Strength	22.20	19.0	180
Bar with Highest Elongation	24.88	27.0	180
Bar with Lowest Elongation	24.36	13.0	160

Physical Properties of Black-heart.

The tensile strength of black-heart is 23 to 27 tons per sq. in., associated with an elongation of 15 to 25 per cent. on 2 in. The yield point is 15 to 18 tons per sq. in. and about 20 per cent. reduction in area. These figures are for results on a 0.564-in. dia. bar. The bend test on a 1 in. × $\frac{3}{8}$-in. bar round a 1-in. radius gives about 180 degrees. Some interesting figures are given in Table X. Unlike other metals, the elongation of black-heart malleable increases with the tensile strength. This is shown in Fig. 18. The material is very soft and gives a Brinell number around 110 and a value on the Shore scleroscope of about 15. It possesses useful magnetic properties and is used to a considerable extent in electrical industries. It has high permeability and very low hysteresis loss and coercive force. Figures are given in Table XI. Greater resistance to rusting

Table XI.—*Magnetic Properties of Black-Heart Malleable.*

Description.	Test A.	Test B.
Maximum Magnetising Force. C.G.S. units	109	107
Maximum Magnetic Induction. Lines per sq. cm.	10,875	11,375
Residual Magnetism. Lines per sq. cm.	5,125	4,500
Maximum Permeability ..	1,500	1,750
Coercive Force. C.G.S. units.	2.5	2.0

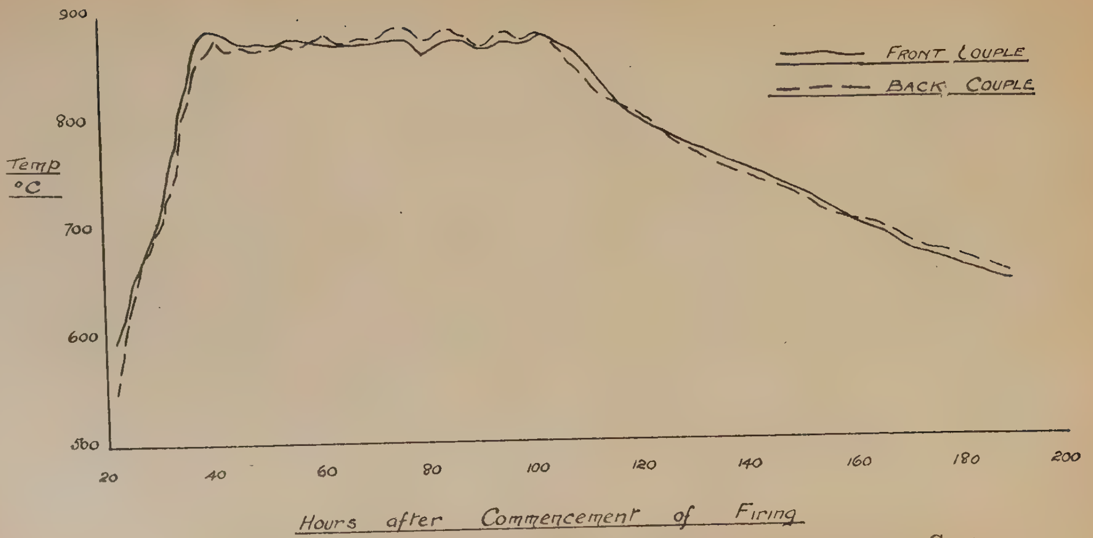


FIG. 17.—TEMPERATURE-TIME CHART OF BLACK-HEART ANNEALING CYCLE.

is shown by malleable than by other ferrous materials of similar shock and strain-resisting qualities. This is probably due to the surface of a malleable casting being practically carbon free.

Machinability of Black-heart.

The free-cutting properties and speeds of machining attained on black-heart malleable are exemplified by the following figures. These were obtained from a well-known firm of machinists who completely finish some 20 to 30 tons of motor car details per week.

Turning and facing flange 10 *in. dia. on a large casting.*

Roughing speed ...	108 ft. per min.
Finishing speed ...	182 ft. per min.

Turning and facing cylindrical piece 6½ in. dia.

Roughing speed ...	140 ft. per min.
Finishing speed ...	400 ft. per min.

Turning and screw-cutting a light sleeve casting

Rough turning... ...	100 ft. per min.
Finish turning... ...	235 ft. per min.
Screw cutting with single point tool ...	170 ft. per min.

This job is one of great accuracy, the working limit allowed being plus or minus 0.0005 in. Precision in the diameter of the thread is secured by working to a dial indicator, and hundreds of the piece are so produced without regrinding the tool.

As regards uniform machinability and absence of hard spots the record of machining 39,207 radiator ferrules 1¼ in. dia. screwed right- and left-hand threads, without regrinding the dies is sufficient evidence.

Picture Frame Material.

It will be seen from the foregoing remarks on machinability that this material will not be suitable for all classes of castings, especially those which have to withstand abrasion and wear. Such requirements can be met by the production of castings with what is commonly called "picture frame" fracture. Fig. 19 shows this feature. It will be seen from this photograph and from the micrographs Figs. 20 and 21, that the core of the material is of usual black-heart quality and structure, but is surrounded by a border or rim which is mainly pearlitic. This material has a slightly higher tensile strength than the normal iron, averaging approximately 26 tons per sq. in., with a lower elongation which runs from 10 to 15 per cent. Bend tests of 90 deg. round a 1 in. radius are obtained. The hardness values taken on the surface are much higher than usual, being 30 to 35 scleroscope (equivalent to about 250 Brinell). This special class of malleable is obtained by slight alterations of the composition of the hard castings. The carbon is higher, at about 2.60 per cent. together with lower silicon and higher manganese contents. The sulphur is unaltered. The " picture frame " fracture can be achieved also by lowering the manganese content, the other elements remaining as before mentioned. The annealing treatment is exactly the same as in usual practice.

Reference should be made to the remarks on the theory of annealing black-heart malleable, where it was stated that when graphitisation was carried on until equilibrium was attained, there was always a certain amount of carbon which was not graphitised, this amount being definite for any temperature. At just above Ar_1 this amount is about 0.45 per cent., and it can only be graphitised by holding at or just below Ar_1 for a sufficient time. The time required is greatly affected by small changes in the composition, *e.g.*, increased manganese lengthens the time requisite to such an extent that the ordinary rates of cooling are not slow enough to permit the final graphitisation, and some of this 0.45 per cent. of carbon is found as pearlite in the annealed material.

It would naturally be thought that this pearlite would be distributed throughout, but such is not the case, and it is always found in the rim as shown in micrograph Fig. 20. Many explanations of this phenomenon have been attempted, but none has met with general acceptance.

The 0.45 per cent. of carbon previously mentioned as existing ungraphitised at Ar_1 is distributed evenly throughout, and, even with this special composition, is graphitised in the core, but in the rim it is considered that decarburisation has always proceeded so far that graphitisation here is restrained. Further, the authors believe that the particular composition adopted produces more sur-

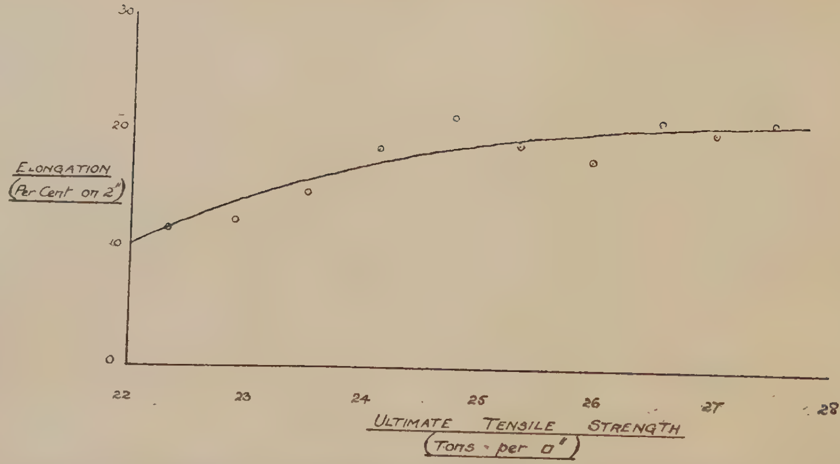


FIG. 18.—SHOWING PROGRESSIVE INCREASE OF DUCTILITY, WITH TENACITY OF BLACK-HEART MALLEABLE.

face decarburisation than is normal, owing to the slightly decreased speed of graphitisation, which would be expected with the lower silicon and unbalanced sulphur and manganese.

Physical Properties of White-heart.

Good white-heart malleable has a tensile strength of 23 to 30 tons per sq. in. and an elongation of 5 to 10 per cent. on 2 in. The yield point is about 16 tons per sq. in., and the reduction in area is about 10 per cent. The bend test on a ⅜-in. bar round a 1-in. radius is from 45 to 90 deg. Some figures are given in Table XII. These figures are for a tensile test bar of ⅜-in. dia. White-heart machines readily and a figure of 90 ft. per min. is representative of well-annealed material. The metal cannot be machined so readily throughout, as the combined carbon content is too high when more than about ⅛ in. has been removed. It is, however, easily drilled through any normal section. No figures have been obtained respecting any useful electrical properties, but it may be expected to possess fairly high permeability. Its rust-resisting properties are like those of black-heart, the surface of the two materials being similar in structure.

Table XII.—*Physical Properties of White Heart Malleable Tensile Bars* 0.375 *in.* (⅜ *in.*) *Diam. Bend Bars* 1 *in.* × ⅜ *in.*

Description.	M. S. tons per sq. in.	E. per cent. on 2 in.	Bend. Degs.
Average of 162 Consecutive Tests	24.60	8.3	57
Bar with Highest Tensile Strength	31.00	4.0	30
Bar with Lowest Tensile Strength	22.80	8.0	95
Bar with Highest Elongation	25.60	15.3	60
Bar with Lowest Elongation	31.00	4.0	30

General Considerations of Costs.

From a perusal of this Paper, it will be evident that the cost of producing malleable is very much higher than ordinary grey-iron castings of similar shape and size. The chief items of increased cost may be briefly summarised as follows:—

(1) Higher cost of pig-iron, owing to necessity of ensuring the accurate analysis of charge, and the special qualities of hematite required.

(2) For black-heart, high operation cost of melting in air furnace, caused by amount of fuel required and heavy expense of maintaining brickwork. For white-heart additional cost of extra fuel for cupola.

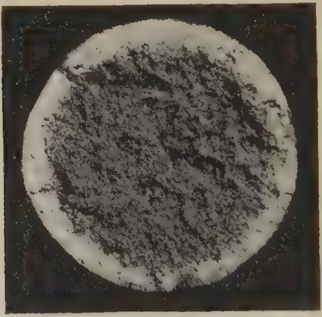


FIG. 19.—FRACTURE OF "PICTURE FRAME" MATERIAL.

(3) Higher melting-losses.

(4) Additional weight of molten metal required to run the castings owing to the necessity of feeders, etc.

(5) Annealing expense covering plant, maintenance of brickwork, and fuel.

(6) Extra cost of cleaning castings run at higher temperature, necessitating sand-blasting in many cases—also further cleaning and barrelling after annealing.

(7) Higher grinding and fettling costs owing to excess metal arising from feeder heads and chipping away of ties not removable before annealing; and

(8) Accurate setting under press or drop hammer to enable the castings to be located in intricate jigs for mass machining.

When reviewing the foregoing items, it is of interest to note that regarding item 4, there is a very great variation in the weight of feeders for different castings, which is caused by the variety of designs. This results in a difference of between 30 and 70 per cent. on good castings per ton of metal melted. It is evident from this that there must be a wide variation in the cost of production, and that any flat rate covering a range of castings could not be satisfactory, either to the founder or the buyer, and is therefore economically unsound.

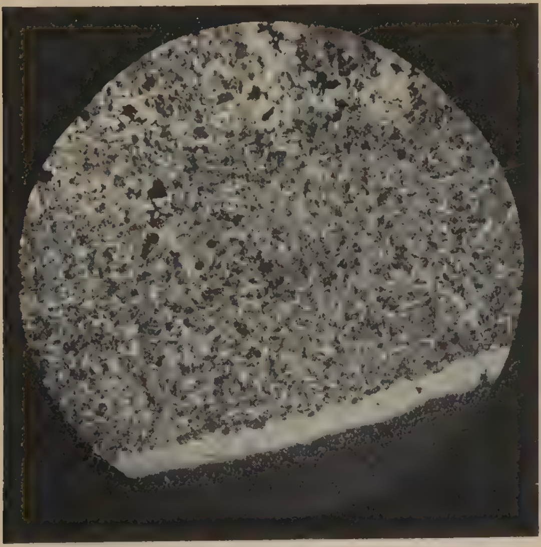


FIG. 20.—RIM OF "PICTURE FRAME" METAL. ANNEALED. ETCHED × 50.

With regard to the question of annealing expense, this vital portion of the process is an expensive operation to carry out satisfactorily, and the annealing cycle cannot be shortened if regular and reliable results are to be obtained. Some firms talk about annealing periods which are very much shorter than those given in this Paper, but the authors up to date have not been able to achieve any of these wonderful results.

It often happens that the malleable ironfounder obtains work from the engineer because a grey-iron casting has failed in service, and the engineer expects to replace it by malleable iron at approximately the same price. Needless to say, this is impossible, although with the reduction which can be brought about in weight by using malleable iron, his ultimate cost is not very much greater, although it may appear so when viewing the prices on the cwt. basis. First-class malleable castings in either black-heart or white-heart cannot be produced except by using the best methods of production, and neither material is equally suitable for all classes of work.

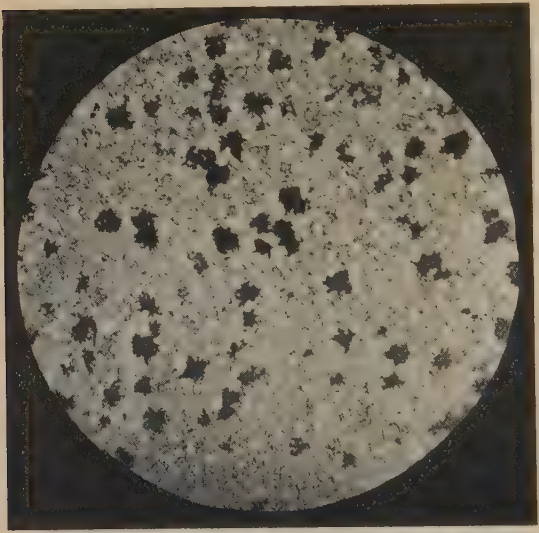


Fig. 21.—Centre of "Picture Frame" Metal. Annealed. Etched × 50.

Extreme sections, both very heavy and very light, are to be avoided in both materials as much as possible. Some designers often try to reduce the cost by lightening their sections to such an extent that this, in some cases, so increases the cost of moulding and annealing that the ultimate cost is greater than if a more reasonable section had been adopted. To achieve success, all founders aim at having customers who are satisfied in every way, but this can only be attained if the customer allows his designer fully to co-operate with him, so that a casting may be produced on a commercial basis which is the result of mutual experience of all concerned.

In conclusion, the authors wish to thank all those who have assisted in the preparation of this Paper, and in particular they acknowledge the permission given by the Directors of Ley's Malleable Castings Company Limited, to publish much of the information contained.

DISCUSSION.

Mr. J. W. Murray (Wednesbury) wrote that the authors were to be congratulated on such a comprehensive Paper on that subject, but a few of their remarks called for consideration. They stated that the blackheart casting must be different in composition. He did not think that was the case. Table XIII gave the analysis of four black-heart castings, each from a different firm.

These varied widely in composition excepting the phosphorus content, and tended to show that there need not be so much consideration for such low sulphur and carbon contents. There was no doubt that with very low carbon irons the silicon could be raised, and there was some relationship between the two. In cases 2 and 3 the castings should not have been good (according to the author's remarks) but they were ideal, both in fracture and microstructure. As the total carbon of No. 3 was 2.65 per cent., it was obvious that the original casting before annealing was at least 3.10 per cent., because the picture frame contained very little carbon. The essential difference appeared to be not chemical composition, but the method of annealing: on the one hand the removal and on the other the deposition of carbon.

Common sense told them that higher carbon in the iron would affect the time of annealing whilst

TABLE XIII.—*Analysis of Black-heart Castings after Anneal.*

No.	Si.	S.	P.	Mn.	T.C.	C.C.	G.G.	Type.	Tensile strength. Tons.	Elongation per cent. on. 2 ins.
1	0.59	0.06	0.02	0.17	1.65	0.37	1.28	test bar	37 tons	7
2	0.66	0.33	0.09	0.47	2.37	0.15	2.22	casting	—	—
3	0.46	0.21	0.09	0.40	2.65	—	—	casting	—	—
4	0.95	0.09	0.02	0.36	1.83	0.04	1.79	test bar	20 tons	15

too little carbon would give difficulties in producing good sound castings. A carbon content of 2.90 per cent. to 3.30 per cent. yielded the best all-round properties affecting time and temperature of anneal, other constituents being suitable. The limitation of carbon content and control of other constituents involved the use of refined irons to secure the best results.

Effect of Heat Treatment.

Malleable casting suffered from ingotism just as other cast products did. Many of them were spoiled by faulty heat treatment. Appended were two micro-photographs of the same casting. No. 1 (Fig. 22) showed the casting as delivered to the users. These rejected castings were examined, and one was heat-treated to just above Ac 1 point. The whole structure was refined, as could be seen in No. 2 (Fig. 23). The refined casting was much stronger and tougher. Malleable ironfounders ought to send out their castings in the best possible condition. Pig-iron makers might give an ideal iron which could be easily ruined by faulty heat treatment; yet so many continued to blame the iron. Malleable castings should be controlled to some extent by the microscope. Greater care was needed with the annealing medium. A casting was broken in two and one half annealed. The white unannealed half contained 0.12 per cent. S. but the annealed half contained 0.23 per cent. The S. content of the new ore was 0.02 per cent.; that of the used ore was 0.21 per cent. The scale adhering to the pans was 0.29 per cent. Should any of that scale find its way into the used ore, it appeared finally to migrate into the castings via the ore. That scale should be kept from the ore.

He asked the authors the following: "When a blackheart casting was to be subjected to a further operation, involving heat effects such as brazing, did not the work done cause the carbon to be taken into the solution, which on cooling forms a zone of pearlite or a high-carbon steel structure, thus restricting all post heated casting to whiteheart malleable?"

Effect of Brazing.

Mr. Evans, in replying to Mr. Murray, could not agree with the suggestion that good black-heart could be satisfactorily made from metal of very variable composition, and that much consideration need not be given to low sulphur and carbon contents. Taking the four examples of which Mr. Murray gave the analysis, No. 1 was a very inferior black-heart, and did not equal the B.E.S.A. specification for elongation, and it was very doubtful if it would give 90 per cent. bend

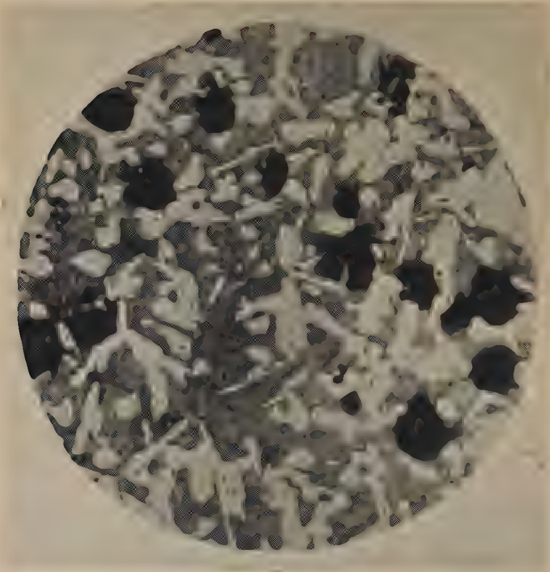


FIG. 22.—MICRO NO. 1.

on the standard bar. The combined carbon content of 0.37 per cent. was responsible for high tensile strength and moderate ductibility. That combined carbon was due to the bad sulphur and manganese balance. A manganese of about 0.37 per cent. would be necessary with that sulphur content to produce an iron which would give normal black-heart physical properties.

Examples No. 2 and No. 3 were not true black-heart malleable, and were apparently attempts to make black-heart from the cupola by raising the manganese content. Such compositions treated as black-heart in the annealing process would give very poor results.

No. 4 was a true black-heart, and agreed fairly well in composition with the requirements stated in the Paper. The physical tests were satisfactory, although the tensile strength would be expected to be higher, considering the composition. It was, however, probable that the iron had been annealed at a high temperature, and that free carbon was present in large nodules, which would account for a strength of no more than 20 tons.

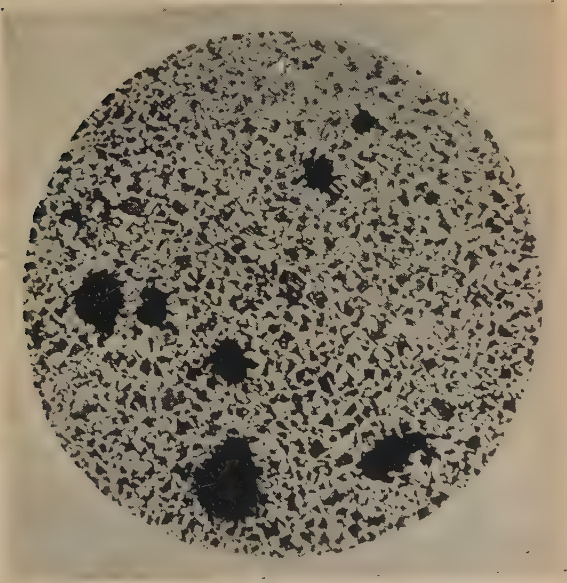


Fig. 23.—Micro No. 2.

The statement that the essential difference between the two malleables was in the one case the removal of carbon and in the other the deposition of free carbon was substantially correct; but the statement that that depended on annealing only was definitely wrong. Graphitisation had been dealt with sufficiently in the Paper to show that an iron which would readily graphitise did not make a good white-heart, and that an iron which would not readily graphitise did not make good black-heart.

The micrographs were of a very poor malleable, apparently an attempt to make black-heart with a high sulphur iron. The refinement had admittedly improved the iron, but had not made it into good malleable. With reference to the question of after-heat treatment of malleable, they pointed out that any heating which involved a temperature of about 720 deg. C. or more would render a black-heart casting brittle. With white-heart the embrittling effect was very much less, and on thin sections, which frequently had been decarburised by the annealing process, the malleability was not impaired at all. A small cycle part would not be suitable in black-heart if it had to be brazed on to the frame. With well annealed white-heart there was practically no carbon there, and one did not get the carbon going back into the solution owing to the effect of brazing.

Malleable from Refined or Virgin Pig-Iron.

Mr. E. Longden said with regard to the production of malleable iron he would like to endorse all that had been stated in the Paper. Undoubtedly they should be proud of the presence of those two gentlemen as representing a company which was far ahead of any other malleable-iron foundry in Europe, and he would say comparable with anything American. In connection with the raw material, he would ask the authors whether they could produce the best quality of malleable iron from refined iron. His experience was that best pig-iron for malleable work was produced from natural ores, and he thought that was the experience of a number of makers. On page 67 the authors said it was sometimes advisable to change the mixture, apart altogether from analytical considerations, as the fluidity and life of the iron might not be all that was desired. But, in his opinion, there must be some inherent properties in the raw virgin metal. Whether or not it was due to some effects of gases in the metal, he was not at all sure; but he would like the authors to enlarge upon that portion of their Paper.

Manganese-Sulphur Ratios.

Mr. J. G. Pearce thought all those who had read the Paper carefully would agree that it represented the best Paper ever given in England on black-heart malleable, and they should congratulate the authors accordingly. In all probability, it would become the standard Paper for the future. On page 102 the authors suggested that low sulphur white-heart graphitised rather than decarburised, and gave a result not much better than the weak grey iron. Perhaps the authors could explain a result of the kind which recently had been obtained in some tests by the Research Association, which was as follows:—Iron of 3.0 per cent. total carbon; 0.6 per cent. silicon, with only 0.015 per cent sulphur—made to B.E.S.A. specification—but which gave 10 per cent. elongation and 120 degrees bend on the standard bar. It decarburised and the degree of carbon removal was 70 per cent. on 120 hours' annealing, which they would regard as normal for a material of that thickness. He did not call that weak malleable.

Referring to manganese, the authors said that it had been found by experience that the atomic ratio of 1.72 times of sulphur (managanese sulphur ratio) gave the best working conditions. He would be glad if the authors could amplify that, because in Papers published in 1925 and 1927. Mr. E. R. Taylor showed that the manganese sulphur ratio should be 1.71. In point of fact these Papers, with some additional work, were summarised at the Sheffield Convention last year. Judging from the work which had been done since then, he believed that that ratio required modification. It would be particularly helpful if the authors could pick out from their experience say a dozen bars of varying manganese sulphur ratio, and so confirm the original view that 1.71 manganese sulphur ratio was based on physical tests. That was rather an important point at that moment.

Improved Grey Iron Available.

Mr. J. Shaw also emphasised the value of the Paper. He was not a malleable expert, so from that standpoint he could not offer much to what had been said. From his recent visit to America he had found that a great advance was being made with grey iron from the use of air-furnace metal. He visited some works a fortnight ago, where they were making practically 100 tons a day from air-furnace metal. In one particular case they had ousted steel, due entirely to the better qualities from that type of metal. He put forward that as a suggestion as grey-iron founders generally were losing work, due to welded material. being used for condensers and similar work, a factor which was hitting them very badly. There was no doubt this American firm had built up a special grade of metal for general application, but especially for break-drums for heavy motor-lorries for heavy duty, which enabled them to cast 100 tons per day of that particular material by means of which they had ousted steel castings practically all over America. There was one point on which he would like some information. He referred to what had been said on page 68: "This material is regularly being machined to fine limits, and small additions of manganese, in the form of 80 per cent. ferro-manganese, to the ladle when pouring improve its machining qualities with little change in the analysis." He would be glad if Mr. Evans or Mr. Peace would give their views as to what effect manganese had in causing ease in machining.

Sulphur-Silicon Ratios.

Mr. F. J. Cook said that reference had been made to the ratios of manganese and sulphur, with a view of eliminating a type of hardness, which prevented easy annealing. In white-heart malleable he had been interested in the ratio of the silicon to the sulphur. In observations over a long period he had found many instances where that was the great ruling effect. It would be interesting if others would look through their records and see if they could find the ratio of silicon to sulphur, or sulphur to silicon, which seemed to have any beneficial effect in black-heart.

Mr. F. K. Neath said that on page 99 the authors, under the heading of sulphur, stated that the sulphur in black-heart must necessarily be kept very low, owing to the fact that it retarded the graphitisation. They also stated that manganese was useless for neutralising the sulphur. He recently saw in an American journal that manganese was being eliminated, and that cerium was being added. The excess cerium used to neutralise the sulphide did not have the harmful effect apparently that excess manganese had. He wondered if the authors had heard of that, or had had any experience of it, as it seemed to him quite an interesting development.

Factors Affecting Fluidity.

Mr. A. E. Peace, replying to Mr. Longden's remark as to refined iron, stated that it was some years since Mr. Evans had been actively engaged on white-heart malleable, so that for the present Paper neither Mr. Evans nor himself had had a great amount of white-heart material to draw upon; and they had had to rely on data which had been sent to them by various friends. As to refined iron, he might make reference to two Papers given by Mr. Hurren and Mr. Field, in which they both stated that they could make better quality white-heart with refined iron than they could with unrefined iron. It was certain that one could get more accurately to an analysis with refined irons than one could with ordinary natural hematite, unless very great care had been exercised in its selection. With regard to fluidity, and occasionally making a rather large alteration in the mixture in black-heart malleable because of loss of fluidity, Mr. Longden had suggested that it was a matter of inherent properties. That might very well be so. In malleable it was the custom to re-melt a large quantity of scrap. The feeders and runners, as mentioned in the Paper, were very considerable, and they were re-melted with a charge; so that if new pig-iron were introduced, one gradually got a cumulative effect of any harmful element which one could not remove from that iron. It was that which happened when they occasionally saw signs of loss of fluidity.

Initial Composition.

Mr. Pearce had criticised the range of analyses on page 4, but he would point out that that was a range of pig-irons which were suitable, and which might be used. He thought Mr. Pearce would agree that an enormous amount of pig-iron was absorbed in the malleable-iron industry to-day with carbon up to 3.8; but he did not suggest for a moment that white-heart malleable should be made from 3.8 per cent. carbon. The scrap which was utilised would be somewhere about 3 per cent., and would reduce that 3.8 pig-iron down to some extent. Mr. Pearce had quoted the 3 per cent. total carbon content, 0.06 silicon and 0.015 sulphur white-heart annealing satisfactorily with 70 per cent. removal of carbon as giving good tests. Mr. Pearce did not mention the manganese content, but he presumed it was exceedingly low.

Mr. Pearce replied that it was low.

Theory of Graphitisation Chaotic.

Mr. Peace said it did not have to be very much lower than the ordinary white-heart grades to make void the remark in the Paper that Mr. Pearce was bringing into question. Whilst the paper had not dealt very extensively with graphitisation, there seemed to be much difference of opinion on the subject of graphitisation, which was the main basis of white-heart or black-heart malleable considerations. He had the conception in his mind that if an iron would readily graphitise, it was more difficult to remove the carbon than if it would not readily graphitise. The only suggestion he would make with reference to Mr. Pearce's iron was that it would not readily graphitise in spite of apparent suitable analysis. Mr. Pearce had not mentioned any chromium content, or any other elements which might restrain graphitisation, such as vanadium. Up to that moment, though he had been searching for eight years to find pig-iron without any chromium, he had never discovered it. He had tried pig-irons from Great Britain, Sweden, India and America, and had not yet discovered one free from this element. As to the manganese ratio 1.72 times sulphur, for that data he cited the previous work of Mr. Evans when engaged on white-heart malleable, and the work of Mr. Hurren, which stated that that was the figure which he worked to, and also the research work of Mr. E. R. Taylor. He was not in touch with all the subsequent work which the Cast-Iron Research Association had done. With regard to Mr. Shaw's question asking what was the effect of manganese in softening the white-iron of low sulphur white-heart, he could only say he really did not know. When Mr. Shaw got up and asked a question, one could be pretty sure that there was no published answer to it. But, very definitely, one obtained an increase of temperature when one added manganese to low-sulphur iron in the ladle, and there was a considerable evolution of gas which might have something to do with the softening effect which undoubtedly was very marked. As to Mr. Cook's reference to the silicon to sulphur ratio, he must say that he had not considered that at all, and could not say that he had noticed any definite ratio which gave good results in black-heart. In answer to Mr. Neath's suggestion whether any cerium had been used in place of manganese to overcome the harmful effects of sulphur, he heard some years ago that a number of other elements were being tried out in black-heart malleable in the States, but the names at that time were not divulged, and since then he had not had any communication on the subject.

THE COHESIBILITY OF RAMMED SAND.

By Ivan Lamoureux (President of the Liege-Limbourg-Luxemburg Section of the Association Technique de Fonderie of Belgium).

[BELGIAN EXCHANGE PAPER.]

Sand in Nature.

When medium sand as taken from the quarry is examined it is found that it has scarcely any power of cohesion. It is very difficult to make it into a lump possessing any consistence. This is due to the fact that the grains of silica are bound together not by a uniform mass but by small colonies of argillaceous matter, so that the grains touch each other at their angles, leaving the natural binding material between them (see Fig. 1).

The Treatment of Sand.

The precise object of treating sand is to distribute the clayey matter in a perfectly regular manner throughout the sand. By treatment in the mill—that is by rubbing the sand—each grain of silica is encased in clayey matter and the sand becomes plastic, thus acquiring its real binding property (see Fig. 2). The object of the work of the aerator is to give the sand greater porosity and to increase its permeability.

In order to observe the effect of the treatment of the sand it is enough to rub it between one's fingers for a few moments. It will be found that sand which is apparently weak at once becomes very strong.

Ramming the Sand.

When sand is pressed on a flat surface the grains arrange themselves according to one of their largest faces, the clay matter is pushed between the grains and the whole forms a very smooth surface. This is why flat castings and horizontal surfaces generally have a very smooth appearance (see Fig. 3).

The ramming of the vertical walls, however, produces a sort of tearing apart of the grains,

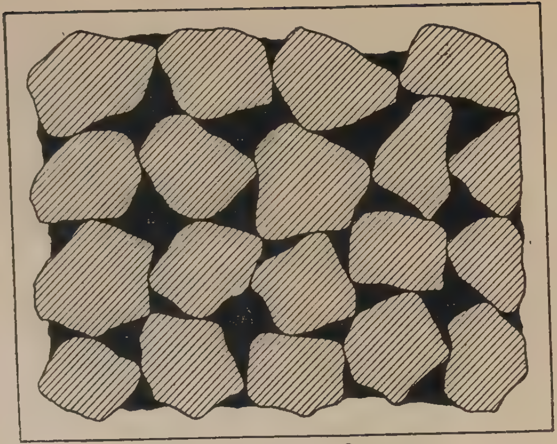


FIG. 1.—SAND AS QUARRIED.

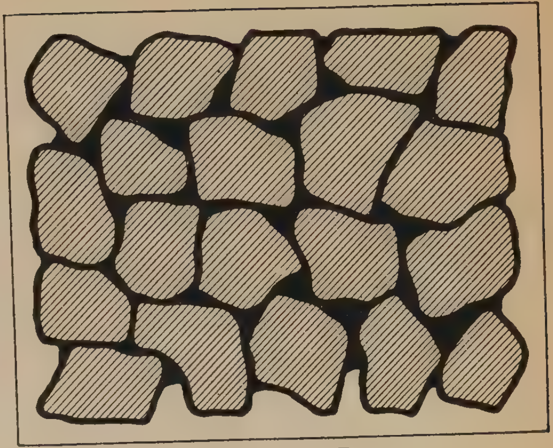


FIG. 2.—SAND AFTER PREPARING.

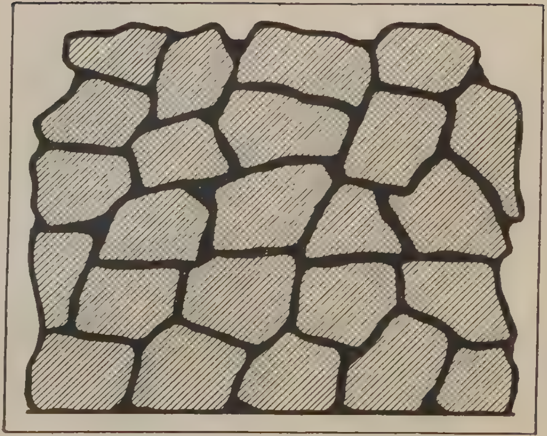


FIG. 3.—SAND RAMMED ON FLAT.

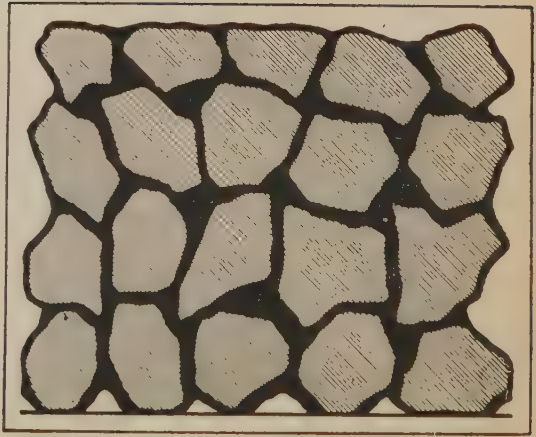


FIG. 4.—SAND RAMMED VERTICALLY.

inasmuch as the grains of sand, being angular, adhere to the walls and turn round several times. When the ramming is finished, the surface instead of being perfectly smooth is actually rough, and it is for this reason that the vertical parts of a mould are generally less presentable and smooth than the horizontal parts (see Fig. 4). Whatever be the method of ramming adopted—by hand, machine squeezing, jarring or slinging—the sand of the vertical walls will be rougher owing to the friction of the grains. It is therefore desirable to devise an arrangement for lateral ramming which will push the sand against the pattern.

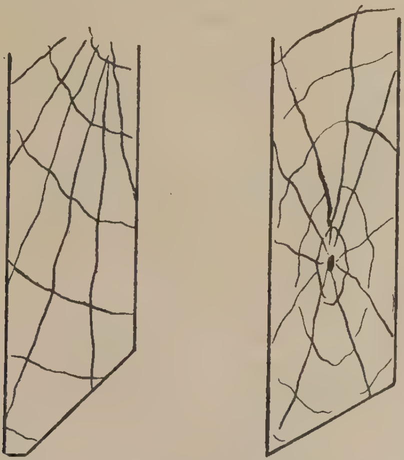


FIG. 5.—SHAPES OF SWEEPING BOARDS.

It is very desirable, therefore, to give all patterns as large a taper as possible. It is quite certain that the founder will make no objection and that the castings will be much better in appearance.

Moulding Without Patterns.

Strickling.—In sweep moulding, a board with the requisite section cut bevelled (see Fig. 5) is generally used. This board cuts the rammed sand

and causes a superficial tearing away which has to be remedied by pressing the sand with the points of the fingers and making several passes with the sweep. This work necessitates smoothing with tools (see Fig. 6). When the castings are dry-sand moulded the moulds are relatively sound, but in green-sand moulding, scabs or blisters are frequently found. This is due to the fact that the rammed sand has been impaired, its cohesion has been affected, and none of the methods of restoring it has proved effective. In

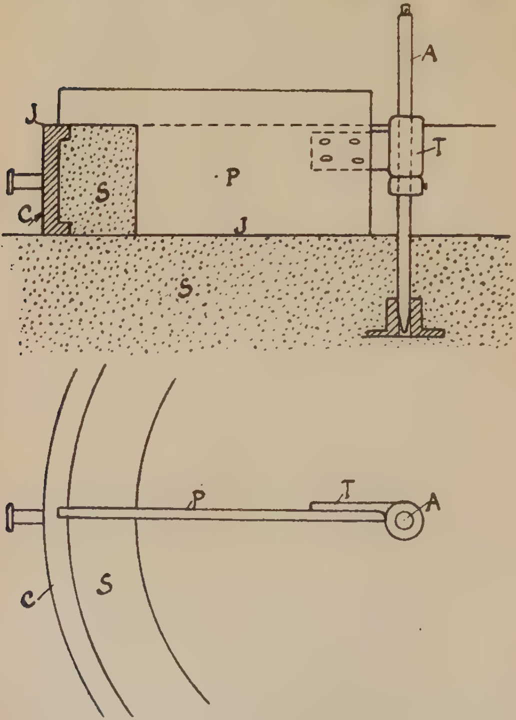


Fig. 6.—J = Joint; C = Box; S = Sand; P = Sweeping Board; T = Spindle Arms; and A = Spindle.

America, for most cylindrical castings, instead of a bevelled board it is customary to use a portion of the pattern fixed to the spindle arm, against which the pattern sand is rammed (see Fig. 7).

As soon as one portion of the mould is finished

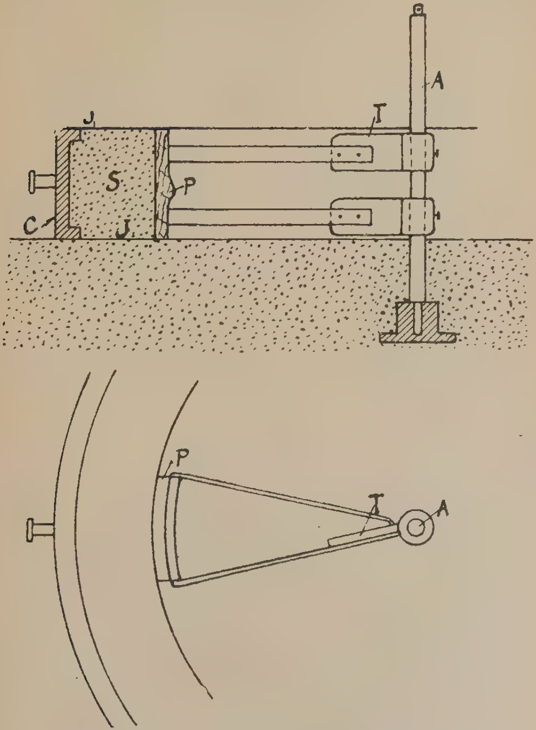


Fig. 7.—J = Joint; C = Box; S = Sand; P = A Section of the Pattern; T = Spindle Arms; and A = Spindle.

the portion of the pattern is removed and the ramming is continued until the whole mould is finished. In this way castings with very smooth surfaces are obtained, as the sand has retained its cohesion and permeability, which are always endangered by the action of the sweeping board and tools. The same method is followed for the inside and outside of the mould.

Moulding With Gauges and Templates.

When castings of uniform section have to be made without patterns, such as those of machine tools, bed-plates and frames of various types, it is customary to sweep the mould by means of wooden gauges on which templates are made to slide so as to determine the dimensions of the casting (see Fig. 8). In this case also the founder will do well to employ the portion of a pattern, which can be removed as often as necessary. When the direct ramming of the walls has been effected the appearance of the casting will be very smooth and the mould will be perfectly sound (see Fig. 9).

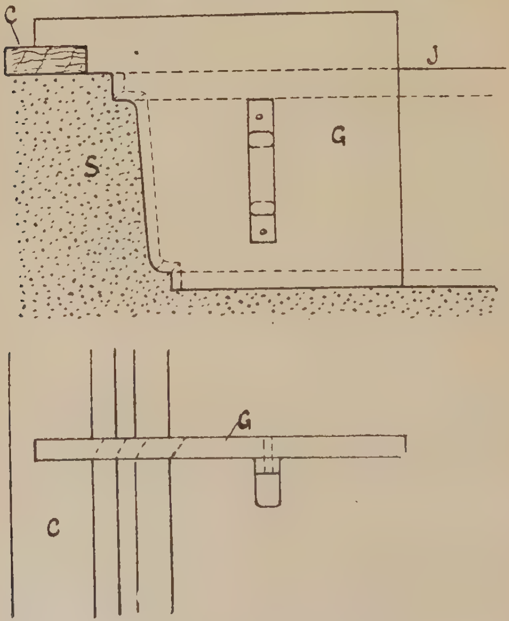


FIG. 8.—C = GAUGE; G = TEMPLATE; S = SAND; AND J = JOINT.

Runners.

While much attention has been paid to the characteristics of the mould, too little regard has often been paid to the runner. The runner receives the molten metal and carries it to the interior of the mould. It is therefore subject to much more severe strains than the mould itself. If it is not perfectly resistant or if scabs are produced in it, all the sand dislodged will be carried into the mould and may spoil the casting. A cylindrical section is best because the release of the gases is effected by channels which are multiplied in number in proportion to their distance from the centre. It has been observed, on the other hand, that runners of prismatic form frequently showed scabs caused by the passage of the metal. When the runner is widened or flared with tools its surfaces are roughened owing to the disturbance of the grains (see Fig. 10). This defect will be demonstrated by using gates, the impression of which has been formed with tools. On the other hand, if the gate has been pressed or rammed by means of a pattern exactly reproducing its form, it will be noticed that the runner on the casting is perfectly smooth and that the down gate has consequently suffered no alteration (see Fig. 11).

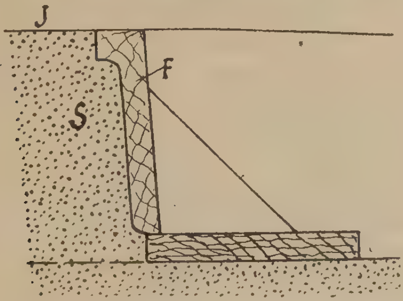


FIG. 9.—S = SAND; F = A SECTION OF THE PATTERN; AND J = JOINT.

Conclusion.

In all the parts of the mould, from the runner to the riser, everything should be done to leave the mould in the condition in which it was rammed. Everything possible should be done to avoid retouching and mending. In short, care should be taken to maintain its cohesibility unimpaired.

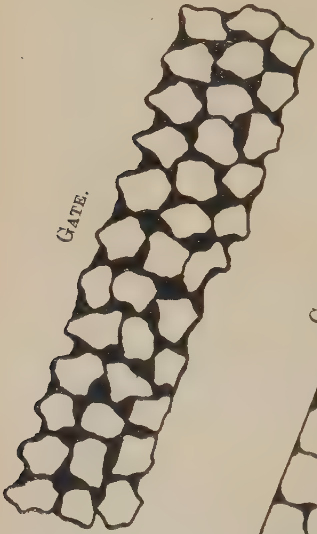


Fig. 10.

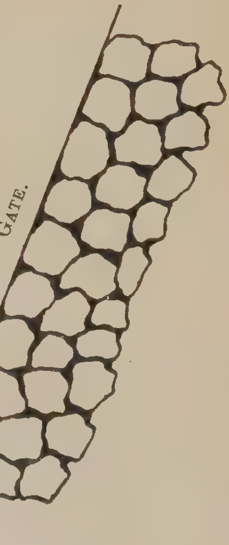


Fig. 11.

DISCUSSION.

Mr. Faulkner, in introducing the subject, remarked that M. Lamoureux's Paper was merely a thought, but a very interesting thought. It was the result of years of experience of handling sand, rather than conclusions derived from a series of systematic tests. The author was a practical man, and probably had not had at his disposal any research organisation. He would just remind them, by going through the first two or three pages, of his ideas, which were perhaps of a somewhat ingenious character.

Mr. Faulkner proceeded to read extracts from the Paper.

American Moulding Practice.

The President said there had been a considerable amount of real research done on moulding sand in the last few years. They had awarded a diploma at that Conference to one of their members for a Paper presented on moulding sand, in which the author went to a very considerable amount of trouble in discussing the various methods of testing sand, and the various tests which could be applied to permeability for general purposes—simple tests which could be used in the foundry. To some extent the Paper seemed a little on the elementary side, as compared with some of the Papers which had been presented to branches, and also the research reports which had been issued in connection with the moulding sands of Great Britain. Though he had not carefully studied the Paper, it appeared to him to throw up a line of thought which was somewhat original to him, though it might not be so to the general body of members. On page 128 the author stated that when the castings were dry-sand moulded the moulds were relatively sound, but in green-sand moulding scabs or blisters were frequently found. He inferred that the author was trying to prove by that his preliminary statement with regard to the position of the grains of sand due to treatment of ramming; but there were many other reasons why a dry-sand casting should be sounder on the average than a casting produced by green-sand moulding, which reasons needed no elaboration from him, because most of them knew the safeguards produced by drying. In the same paragraph the author stated: "In America, for most cylindrical castings, instead of a bevelled board, it was customary to use a portion of the pattern fixed to the spindle arm, against which the pattern sand is rammed." He had had the pleasure of visiting a number of American foundries, but in none of them did he see any loam work being split up, so that he could not answer that. But it did appear to him that it might not be due to the fact that the method used in America of ramming against the portion of the pattern fixed to the spindle arm was the better one, but it might be due to the fact that the American moulding sands are very very different in constitution from the English sands. Very few American sands had any natural bond at all. The bond had to be introduced. Many of them on the recent trip were surprised at the apparent creeping, and found that the Americans did not know much about the moulding sand they used. That was even overcome by drawing across the mould a very thick coat of blacking or facing to produce the necessary smooth skin. He did not see any loam work being split up; but it may be that system was adopted in America because their sands, being of a very dry nature, would not hold up in the plastic state. On page 131, after referring to the runners with downrights, the author said that a cylindrical section was best, because the release of the gases was effected by channels. Then he referred to the fact that runners of prismatic form frequently showed scabs caused by the passage of the metal. The runners he described were what they would usually call oblong, or square runners or downrights. To him that passage suggested a new line of thought. In their own works, on their bigger castings, he would say 75 per cent. of the downrights were square. They had had many troubles, but it had never occurred to him that any trouble could be caused by the use of a square downright as against a round downright. If any member could make any contribution to the discussion on that point it would be of general interest to the Institute. Although he did not want to say that the Paper was elementary, yet it opened several very interesting lines for discussion. Sand was an important problem, because many of their best seams were being worked out, and they were being forced to use rather inferior sand.

Features in Running Castings.

Mr. Cooper (Darlington) said the question of sand interested him very much, and that Paper in particular, for the reason that he had the pleasure of knowing M. Lamoureux. Many years ago he was connected with a number of Belgian and French people when they introduced Belgian sand into England. Many failures which were caused in foundries were not caused on account of the sand, but by the methods of preparing the sand. In the majority of foundries in England, in comparison with the foundries on the Continent, one of the first things to be done was to put in a sand suitable for mixing, because they all knew that sand should not be ground if one wanted to make it in such a form that the gases could escape in an easy manner. For that reason, M. Lamoureux evolved a mill of his own which had corrugated rollers. They all knew the aerator for splitting the sand after mixing in the mill was also evolved therefrom. When M. Lamoureux brought Belgian sand to England he saw it put in a mill containing rollers weighing 5 or 6 cwt., together with a quantity of old sand, and by the time it was removed it was caked in lumps. When it came to be rammed up in the mould it was impossible for the moulder, however skilful he was, to utilise it with success. Although the Paper was elementary, there was no doubt that M. Lamoureux got down, as he said himself, to the elementary principles of all things, because, in foundry work, it was the elementary principles which gave the most trouble. Very often they overlooked them. If they would just revive a little the knowledge they acquired as boys they would escape much trouble. As to the question of the square runners, the point was suggested that square runners were better. Round ones also were better for no apparent reason; but what one wanted in filling the moulds was to get the metal in as easily as possible to prevent any surging.

Sand Face Influenced by Pattern Withdrawal.

Mr. E. Longden pointed out that the author was evidently dealing with green sand the whole of the time; but there was a great mass of castings which were made in dry sand and loam. He was rather surprised to learn that sand would conveniently arrange its flat surfaces, even when rammed on the flat. He was of opinion that it was very unlikely that the grains would so arrange themselves on the flat face of the pattern. It seemed to him that the action really was the forcing of the smaller grains and clayey matter to the surface. Also, in his opinion, the vertical sides of the mould were rough because the sand was rammed against the wooden pattern and the wood grain stuck to the sand and prevented its clean withdrawal. That dragging action was reproduced on the casting, because the flat surface received the greater portion and the sides a minimum of the blacking used for facing. Unless one rubbed the side of the mould one did not get a smooth surface. There was also the roughening action of the metal rising, and the sides were subjected to glare of the metal, whilst the flat surface was covered quickly. The rising metal caused the sand grains to expand and re-orientate. That, to some extent, was the reason why the sides were rough.

With regard to round or square runners, in his opinion, while gas had a very bad effect on scabbing on the surface of the mould, he considered it was partly due to the expansion of the mould or sand face owing to overheating and making an arch. Sand grains held together better as an arch than in a flat surface. That many moulds scabbed was due not to actual gas evolution, but they scabbed because the surface expanded more than the interior. As to Belgian sand generally, he thought they had sands in Britain which were quite as good as the Belgian sands. It was a matter of treatment of the sand rather than the composition of the available sands in Belgium.

Substantiation by Micro Photos Desired.

Mr. Goodwin did not think the author had quite presented his case in a way which was quite acceptable. He would like to ask him how he had arrived, and by what method, at his conclusions with regard to the sectional parts of the mould without photographing it under the microscope? Could the author substantiate them with any actual photographs or any actual data? With regard to the vertical and flat surfaces, Mr. Longden had thrown some light on the matter on the same lines that he would have desired to adopt, but he would go a little further and say that if the pattern was made with the grain of wood horizontally the roughness of the surface was much more obvious than if the pattern was made with the timber in a vertical position. There was a definite slipping effect on the surface and the sides of the mould, which certainly made it much smoother than even a flat surface. If one rammed the sand on the open grain timber one had a distinct impression of that grain of the timber, though the light might not show it up. The vertical lights striking the vertical planes of the mould rather showed up a rougher surface than appeared on the bottom. If one got down on one's knees and examined it as a horizontal surface to the eye, one found that that surface was much smoother than one anticipated, owing to the sleeking effect of the pattern. He would not like it to be thought that the supply of good sand in Britain was running out. In England there was as good sand as ever there was, and large fields of good sand were constantly being found, especially in the older districts, where the sand practicable for moulding was renowned.

As to the point with regard to square or round runners, he was a firm believer in the round runner, for the reason that one had to do away with the corner of the square runner, which, after all, had a tendency to increase the dross in going through to the casting. It helped to make dirt and eventually caused a small scab. The second reason was that it was possible with a round runner, in withdrawing it, even though it be a tapering one, to give it a twist before one withdrew it, thus bestowing a very fine surface on the runner. These details were elementary details, but they all contributed towards making a successful casting. They had to thank the author for giving a new thought with regard to sand moulding; but, at the same time, he was a little bit disappointed that he had not backed up his ideas with some definite data.

Suppliers Should Grade Sand.

Mr. W. H. Poole thought that, however simple, anything which tended to throw light on the usage of sand was of great value. Generally speaking, as foundrymen, they were only just awakening to the value of some systematic search into the very important question of the usage of sand material. It was only in the last year or two that foundrymen had given sufficient thought to the utilisation of sand to the best possible advantage for themselves, and, incidentally, to the quality of the castings which they produced. It might be wise, in the case of English sands, that suppliers should pay more attention to grading the sand at the pit before supplying to the foundrymen. In going round a number of pits in the country some four or five years ago one was rather astounded that it seemed to be merely a question of taking from the pits anything which happened to come along and sending it to the foundrymen, whilst hoping for the best. It was interesting to note, however, that some suppliers of sands were taking a very keen interest in the grading of sands. He was of opinion that there were sufficient sands of fine quality in Britain to compete with anything which might be obtained from the Continent. The Belgians were particularly fortunate, no doubt, in steel moulding sands, in that they had natural deposits which were of very great value. The Paper was certainly very simple, and he was disappointed at the author illustrating his argument with purely diagrammatic drawings. It was quite possible to obtain good and very reliable photographs of the green sand conditions in moulding sands. It brought up a matter which every foundryman could himself study in a very simple way. It was the essence of simplicity, and that could not be over-stressed. Technical men were rather open to having bricks thrown at them by tending to be too academic, and not getting right down on to the floor. How many foundrymen took a systematic test daily, or two or three times a week, on such a simple thing as the amount of silt in the sand? One of the most important and simplest things to his mind was the examination of the condition of the foundry floor sand. Photographs, instead of diagrammatic drawings, would explain much with regard to the surface condition, the cohesion and the permeability of the sands; while no matter what fancy diagram one drew it would not give as practical an insight into the matter. The silting of sands and the influence of the silt upon bond cohesion, and so forth, played an important rôle. The amount of silt, taking five or six foundries, varied from 0.5 per cent. to 45 per cent. of what could be termed flour grade. Flour grade, of course, went through an exceedingly fine mesh. He suggested, in view of the simplicity of the Paper, that foundrymen should do that very simple silt test periodically. He would also refer them to the wonderful work which had been done by Boswell in connection with sand. There should not be a foundryman present who had not got Boswell's book on moulding sand. Boswell was a great authority on the question of sands; and in his book he gave so much information that could be turned to practical value that he, the speaker, was very surprised that the knowledge given had not been more utilised. It would have been interesting to have had more information about grain size, milling sand or milling and aerating it, with some information as to the surface conditions to be thus obtained. Personally, he took something like 40 or 50 tests a week in foundry sands. He had instituted, amongst people whom he could get sufficiently keen, a means of quartering off the foundry floor into sections, and systematically keeping the silt condition in the foundry floor uniform in a practical way as part of the foundry routine. He thought that the time had come when every foundry would have to pay more attention to this very important aspect of the industry than had been the case in the past.

Simple Testing Methods.

The President, in thanking Mr. Poole for his contribution, was not quite clear whether what he called the simple silting test had reference to the method adopted by Mr. Fletcher, of just taking a glass-stoppered bottle and shaking it, and noting the rate of settlement.

Mr. Poole replied that that was one method, and the other was to use the elutriation plant referred to in Prof. Boswell's book and keep standardised the exact figure of silt in the sand. One could use an ordinary sieve or the special sieve which was supplied by the Institution of Mining Engineers, and thereby actually estimate from a given weight the definite amount of silt present (and it could easily be weighed or measured).

The **President** added that he had found a simple test was taking a 1½-in. diameter test tube, and having a small quantity of sand, shaking it in water and allowing it to settle, because, as they were all aware, one could then see a very distinct line where the sand had settled. The heavier grades sank quickly and the silt remained in suspension some considerable time. It might take as long as 24 hours to settle. When, however, one did obtain a distinct line one could take from the sample a comparative test of the amount of silt in one's sand. In three or four cases it had proved extremely valuable to him where there had suddenly developed a patch of dirty casting for no apparent reason, there having been no change in the facing sand. Each time after trying the floor sand that the moulder used by that simple method they had found an amazing quantity of silt in their sand. In each case it was proved afterwards that the man had been on a rather heavier range of casting than usual, and he had turned over his sand rather more. Moreover, for some reason he could not explain, they had used less facing sand. By tipping a couple of barrowfuls of silt-free sand and mixing it in the trouble entirely disappeared. As a result, whenever they got a patch of dirty castings, not scab or gas-holes, but due to dirt, which the moulder always assured one was in the iron, they just took this simple test and satisfied themselves that the floor sand was in proper condition. It was a very valuable and very simple test. One only had to take two or three tests of sand which was giving satisfactory service and compare the amount of silt in good sand with the amount in the sand one was using. They had heard a lot about the use of the heavy, old-fashioned type of mortar-mill. If one wanted to see the difference it made to the facing sand, they should just take a small quantity of sand and put it in a test-tube before milling, and then take a similar quantity and put it in another test-tube after milling, shaking it up in water and allowing it to settle. He would not say they would get a shock, but they would be very interested to see the surprising increase in the amount of silt in the case of average sand. They might be interested to know that in a foundry in Chicago, producing something like 1,000 tons a week of agricultural machinery castings, the whole of the sand testing was done by that method. They used bottles there. The gentleman in charge of the department, Mr. Smith, took him into his laboratory, and there were rows and rows of shelves all round, with at least 2,000 bottles duly labelled with the simple sedimentation tests. Mr. Smith claimed that he reduced his scrap percentage from approximately 7.8 per cent. to 6.45, or about 1.4 per cent. reduction, which he said was entirely due to these sedimentation tests.

General Substantiation Wanted.

Mr. Faulkner, in replying to the discussion, said that though his practical experience was not nil, the only time he had ever rammed a mould in his life was when he was a student at the University and made some floor plates, so that it was perfectly obvious that he was not in a position to reply adequately to the discussion. In justice to the author, he thought one could demand some substantiation of the statement put forward by the members who had discussed the Paper. They had had the Paper in their hands for a fortnight or three weeks, and they had had the chance of making some simple tests. It had been stated by more than one speaker that M. Lamoureux should have submitted some simple micro-photographs instead of diagrams. Mr. Longden had spoken about the expansion of the mould due to radiation of the heat from the rising metal. He submitted, not having had any practical experience of moulding sands, that they did not expand to any extent whatsoever. He suggested merely from imagination that it would be rather the freeing of the water and other gases from the mould, and he did not think that the expansion which Mr. Longden referred to in such an interesting manner did take place. As Mr.

Longden required substantiation of the diagrams, he, on M. Lamoureux's behalf, asked for substantiation of the suggestion as to the expansion of the mould walls. In such a gathering, the part of the Paper which he would have expected to be discussed was the part on scabs. The whole object of the Paper, to his mind, was to impress upon people, who were busy with the fabrication of moulds, that they must avoid mending at all costs. M. Lamoureux insisted that, whenever a mould was mended, it never produced such a good surface, and was even liable to produce a scab. That was a section of the Paper which seemed to escape the notice of most of those who had discussed it. He would convey to M. Lamoureux the interest which had been taken in his Paper, and he was perfectly certain that they would get a most interesting reply from that most charming gentleman.

Author's Diagrams Criticised.

Mr. Arthur Logan wrote that the chief charm of this interesting little Paper was the clear and definite manner in which the author's ideas were put forward without any confusing mass of technical data to obscure them. As far as the main statements in the Paper were concerned, they would be fairly generally agreed to, especially the last conclusion, where the author emphasises the desirability of leaving the mould as nearly as possible in the condition in which it was rammed.

Unfortunately, those who were not so well informed as regards the physical structure of sand as it existed in a mould, may be rather misled and obtain some erroneous impressions from Figures 1 to 4. It was these four diagrams which he wished to criticise in detail. Firstly, he would utter a warning that they should not be taken *too* literally. Possibly the author did not intend that they *should* be taken literally.

Those who had examined moulding sands would agree that the shapes of the sand grains were rather more spherical, and certainly the grain sizes varied more than these diagrams indicate. The shapes of the grains in Fig. 3, for instance, have more parallel faces than it is customary to find in sands. Fig. 12 shows the actual shape of sand grains in Yorkshire and Belgian moulding sands after the clay has been washed away.

When foundries received sand from the quarry the grains were unevenly coated with clay, which formed knobbly and wart-like protuberances on the grains. The object of milling, as stated in the Paper, was to distribute the clay evenly over the grains and thus obtain the maximum bonding and porosity value. In the diagrams in the Paper the sand grains were represented by hatched areas, and the spaces between the grains are completely occupied with what appears to represent the clay. There is no indication of the pore or void spaces which are present. As the pore or void space can amount to over 40 per cent. of the total volume, this was a serious omission. An attempt to picture the structure of sand diagrammatically should show these voids.

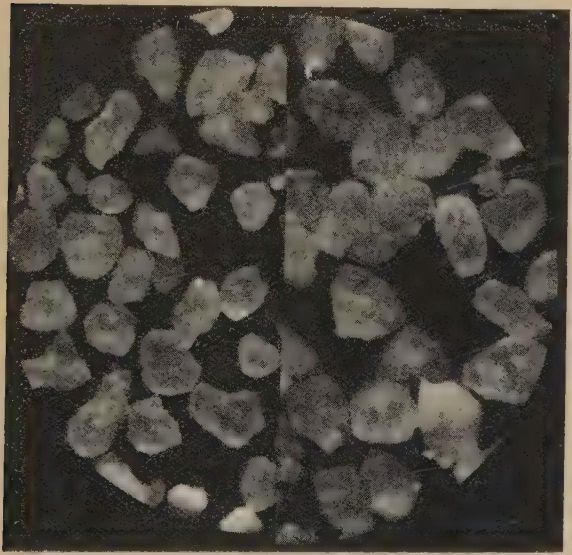


FIG. 12.

A.—Yorkshire sand grains washed free of clay. x 50.

B.—Belgian sand grains washed free of clay. x 50.

For this reason he referred the author to Fig. 13 (herewith), which was, he submitted, a more accurate representation of the structure of sand as received and as rammed in a mould than the diagrams shown in the Paper. Fig. 3 in the Paper is supposed to represent the structure of sand rammed on the flat, but it resembles more the structure of a stone wall than actual sand grains in a mould. He (Mr. Logan) submitted that there was practically no difference in the structure of sand rammed on the flat and that rammed vertically. Both would have the same arrangement as shown in "B" Fig. 13. The main reason why the vertical walls of a mould are rougher is due more to the withdrawal of the pattern than for the reasons stated in the Paper. Some sand always adhered to the pattern, and in withdrawing it this sand was rolled over and over between the pattern and the mould face, thus roughening the surface. The only difference between horizontal and vertical rammed portions of a mould was that in the case of horizontal surfaces the strata of sand rammed to different degrees of density were parallel to the mould face, whilst in the case of vertically rammed faces they were at right angles to it; but it was doubtful if this made any practical difference.

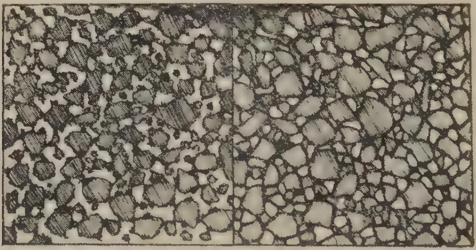


Fig. 13.

A.—Sand as received from quarry.

B.—Structure of sand in mould after milling and ramming.

Altogether the Paper was an interesting contribution, and although it did not reveal any new facts about sand, it would be read with interest by all froundrymen.

Author's Reply.

He first wished to thank Mr. V. C. Faulkner for presenting the Paper, and felt extraordinarily flattered that such a modest contribution should give rise to so interesting a discussion. Primarily, the author neither mentally nor in his Paper has ever wished to stres any particular quality in Belgian sand. The observations related to sands in general. Thoroughly to understand all the peculiarities of moulding and to take into consideration all practical details encountered amongst foundry phenomena the author, the son of a founder, worked as a moulder for a period of six years in various European countries and in America. He is however in a position to state, straightaway, that the sand used in New York State and in the Eastern part of Canada possesses qualities never met with elsewhere.

Microscopic Examination.

The author has microscopically examined moulding sands, but he has only used this study partially to control the observations that he has made in practice. Between the mould itself as made by a moulder and laboratory experiments there is a world unknown—irregularities, differences, surprises due largely to the fact that the foundryman and the scientist do not speak the same language, let alone understand each other.

The author has often seen the manner in which the samples for the laboratory are taken, and can say without exaggeration that the laboratory is entirely at the mercy of the foundryman, who cannot realise the importance of certain precautions. The author is thus inclined to mistrust laboratory results, because chemists totally ignore the way in which the practical man has mixed his sands; the ramming and other moulding operations; quite often the moulders or foremen introduce some error—on purpose or by accident—when sampling.

The author recognises frankly that the diagrams are "imagination," but as Mr. Logan says, the diagrams are not to be taken too literally. Mr. Logan's micro-photographs are well known to the author, who perhaps some day will have at his disposal a laboratory which will allow him to present with exactitude and complete sincerity similar micrographic reproductions.

Patterns.

The phenomena associated with moulding from wood patterns are well known to every founder. The author does not ignore that the roughness of the wood can bring about surface defects in the vertical walls of the mould, but he insists that there is a difference in the structure of vertical walls even when they are made, using well polished metal patterns. Thus it is that he advances the hypothesis that the sand grains do roll over each other during ramming, and that they stop at a certain point of this rotation.

When ramming a flat surface the grain of the sand moves from the bottom to the top without being affected by rubbing against the pattern. This hypothesis is not very extravagant, and the diagram only serves to illustrate the explanation. It should be noted that Fig. 4 should be regarded from the vertical sense.

Runners.

It is sufficient to examine runners of square or polygonal section after sand blasting to satisfy oneself as to the numerous scabs they present. The author can only confirm this hypothesis, that is to say, that the ducts through which the mould gases and steam escape, progressively increase, as they become more distant from the metal, in a round runner, whereas in a square runner the section of these ducts remains constant. It has been definitely established that a cylindrical mould is always sounder than a cubical one.

Ramming Moulds in General.

In his own foundry before the war, the author, who frequently made moulds up to 25 tons, was able to study the difference between strickled and rammed moulds. It seemed to him that certain members had confused loam moulding with dry sand moulding.

Loam moulding ought not to be envisaged in this connection, because it is a branch of moulding quite different from that of sand moulding. Actually, with sand the sweeping board cuts the sand

and tears the mass of the mould, whilst with loam the board carries the sand-mortar without tearing the surface at all. With sand the sweeping board turns with the bevel in front, whereas with loam the board turns with the bevel behind. For instance, in the case shown in Fig. 5 of the author's Paper; if one is sweeping sand one works the board to the left, whilst if it is a loam mould, the same board would be worked to the right. Thus the question of loam moulding does not enter into the discussion.

Conclusion.

One of the principal defects in iron castings in all countries is a scab characterised by an erosion of the mould which carries sand into the metal. The simple observations which the author has thought fit to make on this subject are such that they have convinced him that the serious defect known as scabbing can be remedied by a better understanding of the ramming of sand.

The author is happy in the knowledge that every speaker recognised that the subject was interesting, and that the study of it should be a matter for serious thought by all founders.

STEEL CASTINGS FOR SEVERE SERVICE.

A Summary of Recent American Practice.

By John Howe Hall.

[AMERICAN EXCHANGE PAPER.]

This Paper is written not with the intention of giving data on newly-developed metals suited to endure severe service, but rather of pointing out and commenting upon certain tendencies in recent American practice, especially that of the past decade. During this period, as a result perhaps of experience gained during the war, the properties of the various carbon and alloy steel castings have been studied more carefully than ever before, both by the makers of castings and by their customers, and great progress has been made toward what might be called the rational method of selecting materials, as opposed to the haphazard methods that formerly obtained. Where in past years castings, of certain metals that had proved successful for some particular type of severe service, were tried almost at random, and frequently in defiance of all reason, for almost any sort of use that might be proposed, to-day the nature of the service is studied, the characteristics of a metal suitable for such service as far as possible determined, and the field of available metals searched for those that may reasonably be expected to withstand the conditions to be encountered. When, as is still quite often the case, no suitable material appears to be available, the search for metals possessing the requisite properties is to-day carried out in accordance with carefully-reasoned programmes, far more often than was the case twenty or even fifteen years ago. Too often, in those easy-going days, a foundryman would say—" Yes, we'll furnish our so-and-so steel for your service, and feel certain it will give you satisfactory results "; and, if, as frequently happened, the result was dismal failure, dismissed the case from his mind with the encouraging thought that there were plenty of other profitable orders to be had that did not involve much trouble in the selection of suitable steels.

Perhaps, in the last analysis, the surplus of productive capacity that was a legacy of the war, and which had forced us all to put forth our best efforts to hold our trade in the face of the keenest kind of competition, has been the greatest contributing factor in forcing foundrymen to study their product and sell it only where it may reasonably be expected to pay for itself by the service it gives. The sales, executive, and manufacturing expense of wasted effort, in marketing castings where they fail to give satisfaction, has become a luxury that no concern can longer afford.

There are a number of kinds of severe service for which several distinct types of castings are being marketed to-day. Among these are heavy wear, severe and constantly-repeated dynamic loads, heavy pressure (frequently associated with comparatively high temperature), atmospheric or chemical corrosion, and erosion due to exposure to high temperatures. Frequently, two or more of these conditions may have to be resisted simultaneously, as, for instance, wear accompanied by constantly-repeated heavy stresses, or chemical corrosion accompanied by high internal pressures. Unfortunately, too, in spite of the progress that has been made, it is still too often the case that the design and dimensions of the casting have been determined, and cannot be altered, before the characteristics of the metal that is to be used have been considered, imposing an unnecessary burden upon the engineers called in to solve the problem of furnishing a satisfactory metal for the case in hand.

The Limitations of Manganese Steel.

Fifteen or twenty years ago 12 per cent. manganese steel, the invention of Sir Robert Hadfield, F.R.S., was generally thought of as being suitable for resisting severe abrasive wear of all kinds, and generally no other metal was even considered for an application demanding resistance to wear, until manganese steel had been tried. If, on repeated trials, manganese-steel castings were found to wear out in less time than was expected, it was immediately suggested that the castings furnished were "not up to standard," and they were often carefully examined and tested to discover in what respect they differed from other manganese-steel castings. Only during the last ten years has it been generally recognised that heavy pressure or pounding must be associated with the abrasion if manganese-steel castings are to develop their full power of resisting wear. This is because manganese steel in the heat-treated condition is only moderately hard, about 190 Brinell, so that it is easily scratched by hard particles of abrasive materials; but when severely cold-worked it develops a hardness at the surface of some 550 Brinell, making the surface almost impervious to penetration by gritty materials, even if under heavy pressure. This cold-working, in a great many cases, is accomplished by the material being handled or crushed, as is the case, for instance, in a stone crusher. In applications like this, where the steel is subjected simultaneously to abrasion and severe pressure, the hardness of the successive layers of the casting, as it slowly wears away, is automatically brought to over 500 Brinell by the cold-working that results from the severe pressure, so that the very conditions that tend to wear away the metal, at the same time armour it against further wear by encasing it in a hard, wear-resisting skin; somewhat as the effect of certain diseases upon the bodies of animals is to generate in their blood an anti-toxin that renders them thereafter immune to the illness from which they have suffered.

There is, therefore, a wide range of conditions where castings have to resist what might be termed pure abrasion, in which 12 per cent. manganese steel has been found quite unsatisfactory, either lasting no longer than plain carbon steels, or not outlasting them sufficiently to make up for its higher cost. Typical examples are clay-working and brick-making machinery, Chili mills and similar machines grinding sand or ores, especially wet ores, excavating machinery handling clays or loams containing many fine particles of quartz or other hard minerals, etc. That the failure of manganese steel to resist successfully wear of this type is characteristic of the steel, is demonstrated beyond dispute by the fact that, when tested in wear-testing machines, where pure abrasion is the dominating condition, manganese steel fails to outwear carbon steels of equivalent original hardness, or outwears them but little; while in wearing tests on a laboratory scale, in which the wear is accompanied by heavy pressure, manganese steel outwears carbon steels eight or ten to one.

So far as the author is aware, no steel or iron has yet been found that will resist pure abrasive wear of this type, as satisfactorily as manganese steel resists wear associated with heavy pressure or blows. This is simply another way of saying that, as the severity of the actual wear increases, the ability of all metals to resist that wear rapidly decreases; the limiting conditions are those of the sand blast or the abrasive wheel, which wear away one metal almost as fast as another. The best solution of the difficulty so far found appears to be to use chilled-iron castings when the conditions are such that the strength of the part per unit of cross-section need not be high, and to employ high-carbon steels hardened at the points where the wear is concentrated, in cases where strength is absolutely essential to resist breakage. Steels containing from 0.5 to 2.0 per cent. of chromium and carbon from 0.50 to 1.00 per cent. find many applications in service of this type, the function of the chromium being to intensify the hardness obtained by heat-treatment. Many parts, such as the teeth of excavating machines of various types, are so designed that they can readily be removed for periodical dressing and re-hardening in the smith shop, this practice being practically universal in cases where it is essential that the cutting edge of the teeth be kept sharp.

Because the elastic limit of manganese steel in both tension and compression is comparatively low, some 17.8 to 20.0 tons per sq. in., stresses in heavy service may exceed the elastic limit of manganese-steel castings, unless they are made so bulky as to be unusable. Stresses beyond the elastic limit, constantly repeated, harden the steel just as any other cold work does, and as it hardens it loses its toughness, so that it soon cracks; the crack once started spreads rapidly, and the piece breaks. In other words, manganese steel is not well suited to resist fatigue. In some cases this can be taken care of by increasing the sections of the part so as to bring the unit stresses below the fatigue limit, but often the exigencies of the design do not permit of this, and the casting has to be made of a metal that resists wear perhaps only one-fifth as well as manganese steel, but has greater power of enduring the service stresses. It will take longer to wear out this casting than it would to break the manganese-steel piece, though the latter might last five times as long as the former, if only it could be made heavy enough to stand the severe stresses, so that it would not break, but wear out.

Composite Steels.

One of the most conspicuous examples of the impossibility of applying manganese steel to certain castings subjected to heavy wear, is the large driving pinions with cast teeth often used in rolling mills. Manganese steel castings have proved successful for the pinions of small mills, but, in the large sizes, they have invariably failed by breakage before their teeth were much more than rubbed smooth. The rather obvious solution of making the shaft of a heat-treated steel capable of resisting the stresses, with a manganese steel pinion mounted upon it, has so far not been undertaken, on account of the cost involved. Nickel or nickel-chrome steels, with the carbon as high as prudence will permit, have been used for these castings to some extent, and a number of pinions have been made of ordinary cast steel poured into a mould coated with a paste of fine ferro-manganese, or metallic manganese, and oil. The result is a casting of normal cast steel, with a hard skin perhaps $\frac{3}{16}$ in. or $\frac{1}{4}$ in. thick containing a variable, but high, percentage of manganese and carbon. The extra wear obtained from this hard skin is usually sufficient to pay for the cost of the process.

Autogenous Welds.

In recent years attention has been called to the fact that autogenous welds in manganese steel castings are in the majority of cases unsatisfactory, so that attempts to prolong the life of cracked or worn manganese steel castings used in steam or electric railway track are frequently unsuccessful. In the effort to secure a metal that might be satisfactorily welded, so that worn parts could be renewed and a greater life per pound of investment received than is possible with manganese steel pieces, medium carbon nickel-chrome steel castings have been tried out on an extensive scale in several American cities. The composition of the steel used is C., 0.45 to 0.55; Si, 0.25 to 0.50; Mn, 0.60 to 0.80; Ni, 2.50 to 3.00; and Cr, 0.75 to 1.00 per cent., whilst the physical properties secured from cast coupons treated with the castings, are approximately Tensile Strength, 42 to 53 tons per sq. in.; Elastic Limit, 24 to 35 tons per sq. in.; Extension in 2 in., 12 to 22 per cent.; Reduction of Area, 15 to 40 per cent.; and Brinell Hardness No. 210 to 240.

Engineers are not yet in agreement as to the possibility of securing truly satisfactory welds in worn or cracked nickel-chrome castings of this analysis, and a special committee is at present investigating the subject. It is an undeniable fact that the heat of autogenous welding, and especially of thermit welding, renders the chrome-nickel steel close to the weld exceedingly hard and brittle. Unless the casting is rigidly supported, therefore, an extensive weld such as one joining a casting to a rail, or a repair of a serious crack in the base, is apt to give way in a comparatively short time.

The data so far available as to the rate of wear of these chrome-nickel track casting is confined to cases in which the car wheel rides on its flange in the bottom of the groove at the point where the two rails cross—the so-called "flange-bearing crossings" used in electric railway service. In castings of this type the groove has to be repaired by welding as soon as enough wear—from $\frac{3}{16}$ in. to $\frac{3}{8}$ in.—has occurred to allow the treads of the wheels to ride on the casting. Owing to the low elastic limit of manganese steel, quite a part of this wear in the case of manganese steel castings is actually the flow that occurs while the metal is being work-hardened, and this flow takes place at first quite rapidly. The published figures for the comparative rate of wear of manganese steel and of nickel-chrome steel castings of this type, therefore, are somewhat misleading, and are not representative of the relative lengths of service that would be obtained on tread-bearing type crossings and switches such as are used in steam railway service. No attempt has been made to use chrome-nickel track castings on the steam roads, but a considerable tonnage of electric railway castings has been produced in the past five of six years, and in several of the large American cities they are still being installed on an extensive scale.

High Resistance Heat-Treated Castings.

Probably the greatest advance in steel-casting manufacture during the past decade has been made in the field of heat-treated castings of high strength and toughness for resisting heavy stresses. War time experience familiarised both foundrymen and their customers with the possibilities of improvement in the " common or garden " variety of steel castings so generally made fifteen years ago, and thus paved the way for this development, and the steady increase of power and capacity per unit of weight in machines of all types created an urgent demand for high-grade castings. The change in the situation since 1909, when the author's company put on the market the first heat-treated steel castings (aside from manganese steel) manufactured in America, has been most striking. The late Dr. Henry M. Howe, our Vice-President and Consulting Engineer at that time, assured us then that the properties of those castings had never been equalled or even approached by those of any other cast steel of which he had heard; yet aside from the application for which it was developed, the buckets of ladder-type gold-dredges, no market could be found for castings made of this material. The demand for a steel casting with unusually high strength and toughness simply did not then exist. To-day heat-treated steel castings of the same composition as that of the steel we have made since 1909, are being produced by at least a dozen foundries, and the number of successful applications to which they are being applied is mounting into the scores, if not the hundreds. In some cases the castings are heat-treated by quenching in water or oil and tempering, in others they are normalised and tempered. The range of analysis of steel of this type is about as follows:—C., 0.20 to 0.40; Si, 0.20 to 0.50; and Mn 1.10 to 2.00 per cent.

In addition to the manganese, some makers use vanadium in amounts up to 0.30 per cent. or molybdenum up to 0.50 per cent. Occasionally nickel in amounts up to 1.50 per cent. is used with the manganese. The range of properties obtained from cast-on test pieces of this steel, treated with the castings by quenching and tempering, is as follows:

Maker.	M.S. tons per sq. in.	Y.P. tons per sq. in.	E. per cent. in 2 ins.	R.A. per cent.	Brinell.	Bend ½-in. to 1 in.
A.	35.7 to 44.6	22.3 to 33.4	20 to 27	38 to 62	170 to 190	180
B.	51.3 to 55.8	33.4 to 40.0	13 to 20	25 to 35	250	—

Maker B uses a considerably higher carbon content than maker A, and heat-treats for high strength with moderate toughness. Maker A heat-treats for the maximum obtainable toughness, with moderately high-strength.

The properties obtained by various makers of steels of this analysis, heat treated by nomalising and tempering, are as follows:

M.S. tons per sq. in.	Y.P. tons per sq. in.	E. per cent. in 2 ins.	R.A. per cent.	Brinell.	Bend ½ in. to 1 in.
33.4 to 44.6	17.8 to 29.0	20 to 35	35 to 55	170 to 200	140 to 180

In addition to excellent static tests, cast steels of this analysis have unusually high shock-toughness, published figures for Charpy tests ranging from 13 to 32 ft. lbs., as compared to 6 to 10 ft. lbs. for ordinary cast steels of 0.25 to 0.35 per cent. carbon. The endurance limit also is high, varying from 42,000 to 47,000 lbs. per sq. in., as compared to 33,000 to 37,000 lbs. for ordinary cast steels of 0.25 to 0.35 per cent. carbon.

By the addition of about 0.20 per cent. vanadium the tensile strength and elastic limit of these steels can be increased about 4.4 tons per sq. in. without marked decrease in extension or reduction of area. After normalising and tempering the properties of steels containing about 0.35 per cent. carbon, 1.25 to 1.50 per cent. manganese, and 0.18 to 0.22 per cent. vanadium, are as follows:—

M.S. tons per sq. in.	Y.P. tons per sq. in.	E. per cent. in 2 in.	R.A. per cent.	Brinell.
42.8 to 53.5	26.3 to 37.0	17 to 25	26 to 45	187 to 240

Similar results are being secured by additions of from 0.20 to 0.50 per cent. molybdenum, and steel with equally good properties is being produced in which the manganese averages about 1 per cent. and the nickel about 1.25 to 1.50 per cent.

Nickel-chrome steels of from 0.25 to 0.40 per cent. carbon, with nickel from 1.50 to 2.50 per cent. and chromium from 0.60 to 1.00 per cent., are also being produced, with properties approximately as follows:

M.S. tons per sq. in.	Y.P. tons per sq. in.	E. per cent. in 2 in.	R.A. per cent
40.0 to 53.5	24.5 to 33.4	15 to 25	25 to 40

Industrial Applications.

As a rule the chrome-nickel steels are being used in applications where the castings must have not only great strength and toughness, but the ability to resist wear as well, as for instance, in the treads or shoes of tractors, tanks, and "crawler type" steam shovels. Certain of the tractor manufacturers are using 12 per cent. manganese steel for these castings, while others demand nickel-chrome or some other machineable type of heat-treated cast steel. The advocates of the machineable steel point to the fact that the fits between the pins and their holes are not as good in manganese steel as in the nickel-chrome steel, and claim also that the manganese castings, on account of their low elastic limit, stretch in the pin holes and so get "out of pitch" with their sprockets. This latter claim is vigorously denied by the advocates of 12 per cent. manganese steel, who point further to the fact that the castings of the latter steel are received from the foundry ready to install on the machine, without expense to the tractor maker for heat treatment, machining, and loss of defective castings.

The ability of manganese steel to resist the wear to which tractor shoes are subjected is a further argument in its favour. As so often happens in similar cases, very few comparative tests of the two metals under parallel conditions have yet been made, so that it will probably be some time before the question of which type of steel is the better for this service is satisfactorily settled.

Successful applications of the high-strength cast-steels include motor truck wheels, various heavily stressed parts of motor trucks and machinery, anchor chain, coupler knuckles for railway cars, locomotive drive wheel-centres and other locomotive castings, and even large-sized locomotive frames, which are now being produced in quantity of several different types of alloy steel, usually normalised and tempered. The progress that has been made of late years by foundries producing locomotive frames is evidenced by the fact that they are now ready to accept a specification which will apply to frames, as well as to other heavy castings, calling for minimum physical properties (as shown by integrally cast test pieces) as follows: Maximum stress, 37.5 tons per sq. in.; yield point, 22.6 tons per sq. in.; elongation on 2 in., 22 per cent., and reduction of area, 40 per cent.

This is a marked contrast to the American Society for Testing Materials 1918 Specification, "A 27—16," applying to steel castings for railway rolling stock, which called for the following properties:

Grade.	M.S. tons per sq. in.	Y.P. tons per sq. in.	E. per cent. in 2 ins.	R.A. per cent.
Hard ..	35.7	0.45 × M.S.	15	20
Medium ..	31.2	,,	18	25
Soft ..	26.7	,,	22	30

It will be seen that even on the coupons from so large a casting as a locomotive frame, the foundries are now willing to guarantee minimum values for extension equal to, and for reduction of area considerably better than, those of the 1918 specification for "soft" steel, and at the same time a tensile strength equal to that of the 1918 "hard" grade, and a yield point considerably higher than that of the 1918 "hard" grade.

A large amount of work is being done to determine the relation between the properties of the steel in various parts of heavy castings, as shown by tests trepanned out with a core drill, and those of tests cut from cast-on test pieces. In several quarters the impression prevails, based upon scanty and insufficient evidence, that if only the proper procedure be employed in the heat-treatment, core drill-tests from heavy castings can be made to give properties as good as those of the coupons. Several of the more progressive foundries are in possession of sufficient data to show that this is not true, and that the properties of the core drill-tests vary greatly, depending upon the part of the casting from which they are taken, and other factors as yet undetermined. Within the next few years sufficient data will be collected to enable an intelligent specification to be drawn for the properties of tests trepanned from castings. At present such data are largely lacking.

Heat Treated Castings.

A curious perversion, as it were, of the present efforts to substitute heat-treated cast steels for the plain steel castings formerly furnished, wherever the increasing severity of the service stresses demands it, is the specifying by several railways of 12 per cent. manganese steel for a number of comparatively small truck castings, in which wear is not involved. Breakage of regular grades of steel castings in this service has been frequent, and better castings were sought by those in authority. Learning of the good results received from 12 per cent. managanese steel castings in many classes of service involving wear, and finding them to be tough and strong, the shop foremen have specified them for repair work, regardless of their greater cost, their total lack of machineability, and the fact that the service does not involve wear, the one condition that justifies the purchase of 12 per cent. manganese steel. Several grades of heat-treated machineable castings could be purchased from any one of a number of foundries that would be more satisfactory than manganese steel; but the latter has been tried and found equal to the stresses imposed upon it, and for the present that is enough for those who are doing the specifying and the buying.

Those who, like the author, have been advocating for years the use of mild cast steels with manganese from 1 to 2 per cent., and who have steadily pointed out the falsity of the widely held opinion (first shown to be false by Guillet) that manganese in these proportions makes steel brittle, have been disturbed of late by the tendency of some of the shops now developing these steels to go too far in raising the strength and elastic limit of their castings at the expense of the toughness. Several concerns which have only comparatively recently undertaken the manufacture of these steels, have become so enthusiastic over the possibilities of securing high elastic limit in their castings that they have gone to extremes in this direction, and are, in the author's opinion, producing castings with far too little ductility, especially ductility under shock. By using a relatively high-carbon-content, a high content of manganese, and a low temperature for the tempering that follows normalising, the tensile strength and the yield point are in some cases being raised to figures almost undreamed of a decade ago, but in the rage for high elastic limit, the vital necessity of toughness and ductility is being forgotten.

After all the efforts that have been made to convince engineers that steels containing 1 to 2 per cent. manganese, when properly made, are not brittle, it is a pity that castings should be turned out by reliable firms that are so strong and relatively brittle as to be liable to fail suddenly and unexpectedly in service, and thereby to spread again the false impression that manganese in these quantities makes steel treacherous and brittle. Unfortunately, too, a great many of these over-strong castings have gone into locomotive service, exactly the place where the failure of a casting will be the most disastrous, and where such a failure will be brought to the attention of the greatest number of people.

Heat Resisting Steel Castings.

" Valves, flanges, and fittings for high-temperature service " has of late become a familiar phrase to engineers, because of the discussions before a number of technical societies over the question of specifications for these important parts. The great increase in the temperature and pressure of superheated steam generated in modern power houses, and the equally high temperatures and pressures used in the oil refineries and cracking plants, have made the manufacture of valves and fittings for this severe service a difficult task. Specifications are now in existence for castings to be used at temperatures up to 400 deg. C., and certain engineers are demanding that specifications be drawn for castings capable of withstanding even higher temperatures. Mention is freely made of steam being generated at 1,400 lbs. pressure and even higher, and in the oil refineries temperatures as high as 535 deg. C. and pressures up to 900 lbs. are sometimes encountered. Tensile and other tests at these elevated temperatures are being made on the metals used in valves and fittings in the effort to find those that retain the maximum possible proportion of their " cold " strength at higher temperatures.

It has not taken long for testing engineers to discover that at these high temperatures the ordinary " short-times tests " are of relatively little value as a check on the behaviour to be expected of the metals in service, as " creep " or slow stretch has been found to be the determining factor in the life of the fittings. Stretch at a rate so slow that only after days or weeks does it become measurable with delicate apparatus has been found eventually to cause failure of valves and fittings, so that to-day the leading makers of these parts are carrying on extensive investigations of the amounts of this slow stretch or creep at elevated temperatures. A new property, the "creep point," has been added to the familiar quartette—tensile strength, elongation, extension, and contraction, and to obtain a metal with the highest possible creep point at working temperatures is the constant aim of the manufacturers.

Sound Castings an Essential.

Some of the makers of these parts use plain carbon steel, some use a steel with manganese from 1 to 2 per cent., and some employ nickel, nickel-chrome, or other alloy steels. Whatever be the composition selected, the soundness of the castings is the most important factor in the production of satisfactory parts, for a casting of low tensile-strength steel that is entirely free from piping, shrinkage cavities, sand inclusions, or blow holes, will as a rule endure longer under severe service conditions than an unsound casting of much stronger steel. In the effort to ensure the production of satisfactory castings, designs are being carefully revised by the foundryman and the designer, in order to eliminate all features that make it difficult to secure sound castings, and methods of production in the foundry are being intensively studied. The best size and shape of gates, sink heads, etc., for each pattern is carefully determined by the examination of check castings, and once the best methods have been determined, the utmost pains are taken to standardise patterns and equipment so that none but the desired procedure can be followed. By hydraulic tests, by cutting up castings, and in the case at least of some concerns with an appreciation of the advertising value of "something new," by X-ray examination, the soundness of the castings is subjected to the severest scrutiny, in an effort to eliminate the occasional defective ones. In the case of at least one power-house recently erected, the specifications called for the X-ray examination of every cast steel valve and fitting furnished, and the rejection of any casting found to contain cavities or sand inclusions of sufficient size to be considered harmful to its strength.

The nickel-chrome alloys containing very high proportions of nickel and chrome, so extensively produced to-day for castings subjected to temperatures above a red-heat and to chemical corrosion, do not come within the scope of this Paper because they are not steel. They are made in a great variety of shapes for tempering, case-hardening and cyaniding pots, resistance grids for industrial heating, parts for furnaces used for heat-treating, enamelling, glass-making, etc., and countless similar applications.

Stainless Steels and Irons.

The stainless steels and irons containing from 12 to 18 per cent. chromium and carbon not over 0.50 per cent. and their various modifications, which have been produced in large tonnages in the form of forgings and rolled bars, have not yet been extensively used for the manufacture of castings. The concerns that have been pushing these metals in rolled and forged parts naturally have not wished to engage in the manufacture of castings, because they lack both the equipment and the experience to do so with success.

On the other hand, the steel foundries have been reluctant to undertake the work, on account of their inexperience in handling special steels that have to be given careful attention at almost every stage of their manufacture. As a result, only the concerns already engaged in the manufacture of the high nickel-chrome alloys have been in a position to undertake the manufacture of stainless steel castings with any chance of immediate success, and they naturally have not wished to multiply too much the number of different metals they make.

During the next few years the manufacture of castings of stainless steels and irons and similar metals will undoubtedly be developed on a large scale, since the opportunities for applying these metals in shapes that cannot be made of rolled or forged material are numerous, and are already being called to the attention of foundry executives.

DISCUSSION.

The following contribution was received from Sir Robert Hadfield, Bart, F.R.S.

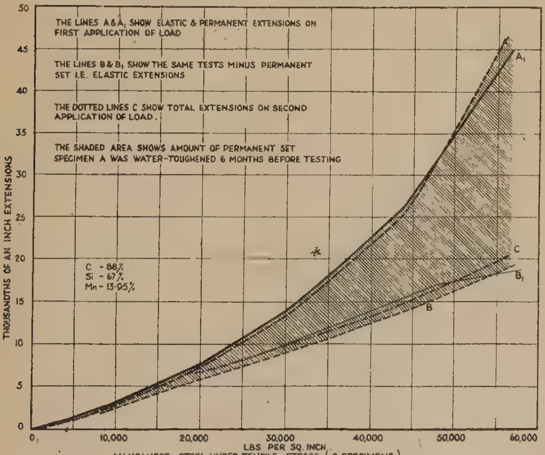
Introduction.

I have read Mr. J. H. Hall's Paper on "Steel Castings for Severe Service," and congratulate him on this interesting contribution. As one of your honorary members, a privilege I esteem most highly, I was appealed to by your Past-President to send a few comments on the Paper, which I have pleasure in now doing, and hope these will be of interest, specially in relation to the references made by Mr. Hall on the subject of manganese steel.

I would like to take this opportunity of expressing my thanks to Mr. Hall's Company, and my friends of long standing—Messrs. The Taylor Wharton Company—for the great interest and help they rendered, now many years ago, in the development of my manganese steel in the United States. In this they were assisted by my friend, the late Professor H. M. Howe, whose work, "The Metallurgy of Steel," published in 1890, dedicated as it was to Sir Lowthian Bell, was of such great assistance to us all in the earlier days of modern metallurgy (1870-1900).

It is now some forty years ago since I invented this special steel and its treatment, and my metallurgical friends have been kind enough to say this steel was the origin of the present age of alloy steels, opening up, as it did, the vista of the many other wonderful combinations of iron which followed and are obtainable by the use of various elements added to iron.

I am glad to find the author from his wide experience and in his statements fully confirms that manganese steel has more than fulfilled the expectations I formed at the time of its discovery, in regard to its probable utility and importance; also that, as now shown by its ever-increasing use, very great benefit has been derived by its users throughout the world.



MANGANESE-STEEL UNDER TENSILE-STRESS (2 SPECIMENS).
DATA FURNISHED BY PROF KENNEDY, (NOW SIR ALEXANDER KENNEDY)

FIG. 1.

It will probably be of interest to those who may happen to read these remarks to know that manganese steel, including its heat-treatment, is to-day exactly the same type of material which I invented about 1882, that is, there have been no changes or alterations in composition or general methods of manufacture.

Before writing these notes I took the opportunity of looking over my original and exhaustive Papers on manganese steel, read in 1888 before the Institution of Civil Engineers and the Iron and Steel Institute, and may add that with hardly an exception I cannot see anything of importance to alter or change, whether as regards my original experimental work or the conclusions at which I then arrived, thus showing that my invention was indeed a basic one and founded on correct scientific and practical principles. The recognition of the value of this invention by so many bodies and societies, scientific and technical, and by the many honours they have been kind enough to bestow upon me in my own country, America, France, and elsewhere, has naturally afforded me the highest satisfaction. Not the least is that bestowed by the Institute of British Foundrymen when in 1914 you elected me one of your honorary members.

In the Paper now under discussion Mr. Hall describes in an interesting manner a number of facts about manganese steel, all of them known long ago in this country, and therefore it is hardly necessary to deal with some of his remarks as they do not represent anything new to us in England, the home of the invention of this steel. I beg, however, to make the following comments, which I trust will be of general interest.

Work-Hardening Qualities of Manganese Steel.

Mr. Hall presents certain explanations as to the work-hardening nature of manganese steel in service, and states that these were not known, defined, or understood until some fifteen or twenty years ago. It is quite true that there has been in the past much misconception prevalent regarding this point by those who had not studied or were not fully conversant with the subject. In this respect I may, however, remind him that in addition to having noticed these facts, my intimate friend, the last Professor Floris Osmond, the famous French metallurgist, accurately described and explained, some thirty-five years ago, the qualities which the author now mentions as not having been known until comparatively recent times.

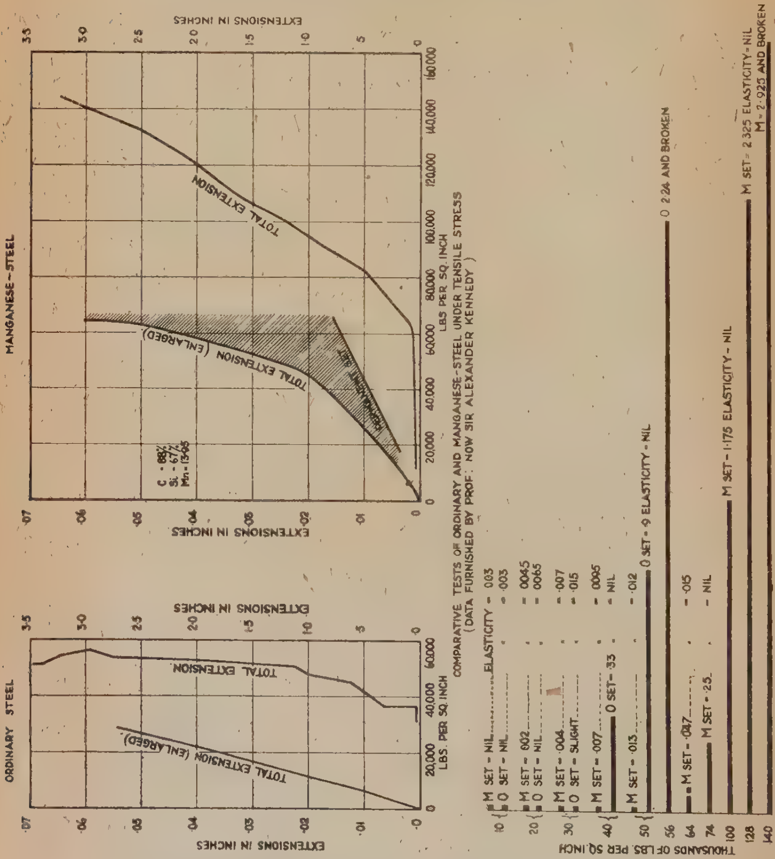
With regard to what may be termed the work-hardening qualities of manganese steel, that is, as produced by working or pressure at ordinary atmospheric temperatures, during the discussion on the Report of the Hardness Tests Research Committee of the Institution of Mechanical Engineers in November, 1916, I gave a full description and explanation of these most peculiar qualities, also of its valuable behaviour in this respect. A full and adequate reply as to why these remarkable changes occur is still not clear, and leaves room for further research. In this respect, research, and still research, is ever the motto of the metallurgist.

Elastic Limit and Yield Point of Manganese Steel.

With reference to the statement by the author regarding the elastic limit of manganese steel, namely, 17.8 to 20 tons per sq. in., I presume that when he refers to this he really means yield point, as the true elastic limit is much lower and not easily determined. If yield point is meant, I consider his figures somewhat too low. Data on this point were quoted in my original Paper already mentioned, when I showed that a tensile bar of manganese steel possessed a yield point of the order of 24 or 25 tons per sq. in. In compression the yield points are somewhat higher, being of the order of 35 tons per sq. in.

In relation to mechanical qualities, I refer the author, also any other inquirers on this point, to pages 52 to 55 in my original Papers already mentioned, and published in 1888, also to the interesting diagrams there shown in Plate 2, Figs. 4, 5 and 6, shown herein as Figs. 1, 2 and 3, which were prepared for me at that time by the kindness of Professor, now Sir Alexander Kennedy, F.R.S., who was then Professor of Engineering of University College, London. By the kind permission of the Institution of Civil Engineers I am allowed to present these, as they will no doubt be of interest to those who read these present notes of mine.

The two Papers in question described the numerous compositions produced in my research, including the one now known throughout the world as the Hadfield manganese steel. They also described the method I invented of obtaining the wonderful toughness noticed in manganese steel; that is, by heating to a high temperature, about 850 deg. to 1,050 deg. C., and quenching preferably in cold water or other suitable cooling medium.



COMPARATIVE TESTS OF ORDINARY AND MANGANESE-STEEL UNDER TENSILE STRESS (DATA FURNISHED BY PROF: NOW SIR ALEXANDER KENNEDY)

Fig. 2 (left)

Fig. 3 (right)

Manganese steel in its natural "cast" condition is not at all tough, but extraordinary toughness is obtained, as evidenced by tensile testbars whether from cast or forged materials. In the forged and toughened condition, a tenacity of between 60 and 65 tons tenacity per sq. in. is obtained, and elongation on 8-in. lengths of no

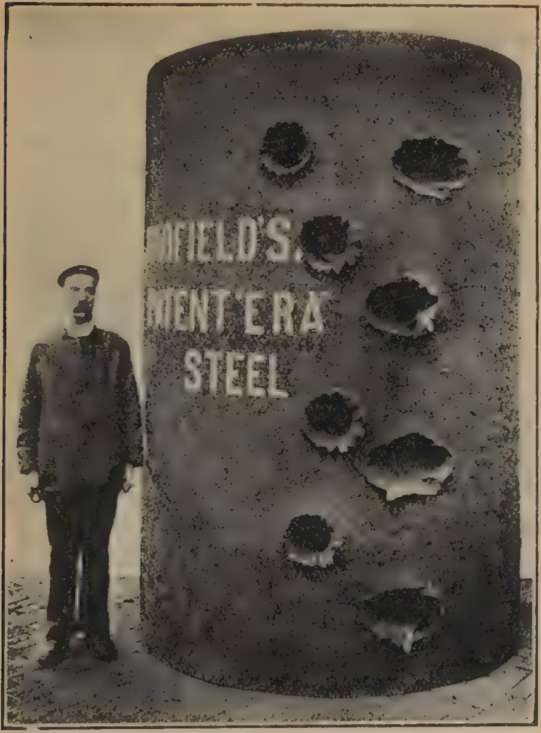


FIG. 4.—AMMUNITION TUBE OF THE HADFIELD "ERA" CAST STEEL.

This tube was attacked by common shell, semi-armour piercing shell, armour-piercing shot of 6-inch, 7.5-inch and 9.2-inch. calibres, and up to 2,040 F.S. striking velocity. In the case of one round 11,000 tons of energy was expended at one impact. Total energy expended on the tube was 50,000 foot tons. This tube is of Hadfield's "Era" steel cast to shape, and has been neither forged, rolled, pressed, nor stamped.

less than 50 to 60 per cent., in some cases over 70 per cent.

It will be seen that this result is exactly the reverse of that obtained with carbon steel. By heating carbon steel, even to a much lower temperature and quenching in cold water, as everyone knows, the resultant product is exceedingly hard and brittle. For medium and high-carbon steel the Brinell ball-hardness is of the order of 550 to 700.

During the discussion (1888) which took place on my Papers, Sir Alexander Kennedy gave a long, interesting and full account of the tests he had carried out, including the determination of the modulus of elasticity. The diagrams prepared by him for me are so interesting that I reproduce them from the original Paper by the kind permission of the Institution of Civil Engineers. Repeat tests now made give the same results, showing how satisfactory was the original composition determined so long ago.

Figure 1 shows the stress-strain diagram for two specimens of manganese steel (C 0.88 per cent., Si 0.67 per cent., Mn 13.95 per cent.) under tensile test. The curves A. and A.1. represent the total extension of the two specimens on the first application of load; that is, the sum of elastic and permanent extension. The lines B. and B.1 indicate the elastic extension only. The shaded area, therefore indicates the amount of permanent set, and the dotted lines C. show the total extensions on the second application of the load.

The specimen bar A. was toughened by water-quenching about six months before the actual testing took place, this being done in order to ascertain whether secular changes might have occurred. The specimen A.1. was toughened shortly before testing.

Fig. 2 is a stress-strain diagram for ordinary steel. It shows the total extension on two scales, that on the left being fifty times greater than for the diagram on the right, which was continued until rupture occurred.

Fig. 3 shows comparative stress-strain diagram for manganese steel on the same scales, that is, the total elongation is shown enlarged on the left and at a scale fifty times smaller on the right, where it is continued until fracture of the specimen.

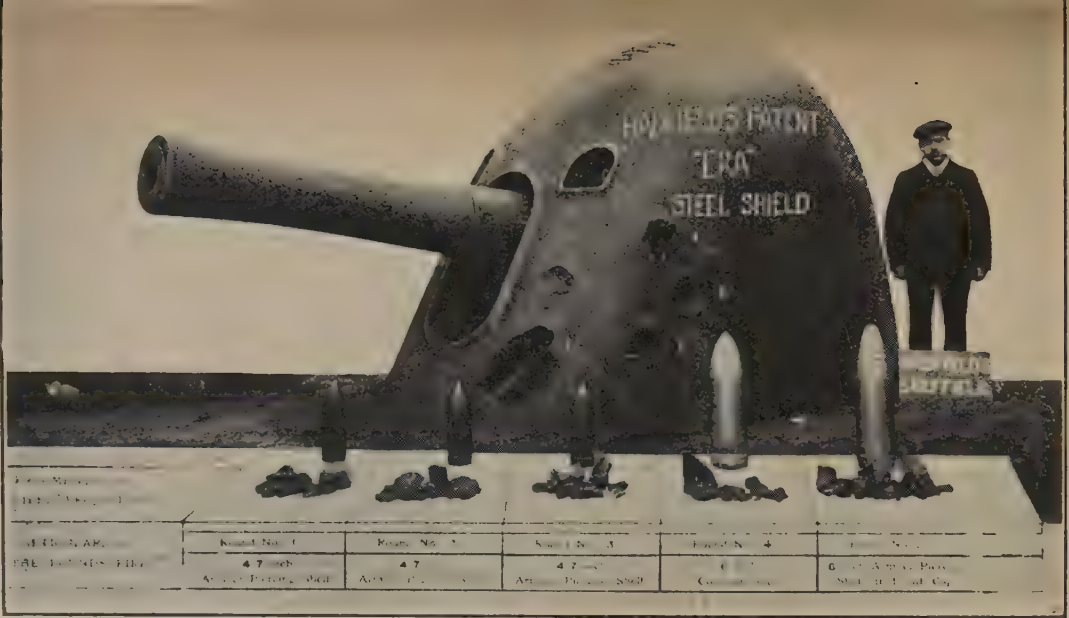


FIG. 5.—" ERA " CAST STEEL SHIELD (HADFIELD'S PATENT) FOR 6-IN. GUN MOUNTING AFTER FIRING TRIAL.

Five rounds, comprising 4.7-inch armour-piercing shell, 6-inch common shell and 6-inch armour-piercing shot, were fired against this shield, giving a total striking energy of 8,950 ft.-tons on an area of impact of only 13 square feet. Round 5040 (6-inch capped A.P. shot) represents a very severe test; the striking velocity was 2,050 f.s. and the striking energy 2,928 ft.-tons, which is equivalent to perforating 10½ inches of mild steel or 8 inches of Krupp hard-faced armour. It will be seen that very little damage was done to the shield, and that it would have offered full protection to the gun's crew and mounting.

These two interesting diagrams, Figs. 2 and 3, permit comparison side by side of the elastic set of ordinary and manganese steels.

Sir Alexander Kennedy.

It is interesting to note that Sir Alexander, who rendered much help to me by making these original tests and other investigations on the mechanical qualities of manganese steel, although now over 81 years of age, is happily and most actively still with us. He has been President of both the Institution of Civil Engineers and the Institution of Mechanical Engineers. By his sound engineering work and practice exercised over a long period of time he has indeed set a striking example to all of us.

I am glad to tell our members that only the other day I had the pleasure of meeting Sir Alexander, hale and hearty, on the golf links at Tandridge, in connection with the meeting of the Engineering Golfing Society. Although he does not now play "the great game," he is still as much interested as ever in the performance of his brother engineers, and many years ago presented the prize known as the Kennedy Cup, for which there is an annual competition.

May he long remain with us to help on the profession of engineering, which has assisted so much in the world's progress during the last hundred years, and the Centenary of which, namely, that of the Institution of Civil Engineers, a Body now over 10,000 strong, was celebrated with such success only a few weeks ago (June, 1928). At this Conference, Sir Alexander assisted on the proceedings, and presided over one of the sections.

Steel of Higher Manganese.

With reference to the type of steel mentioned by the author, of somewhat higher manganese than that usually present in ordinary carbon steels, from about 1.00 to 2.00 per cent., I may say in passing that my firm first made steel of similar composition as far back as February, 1894. Later on, practical applications of this composition were made and the material sold commercially, considerable quantities being produced in the years 1904 and onwards.

Heat-Treated Steel Castings.

I note that the author, Mr. Hall, describes heat-treated steel castings possessing high strength and toughness. He states that his company in America first put on the market in 1909 such steel castings. I congratulate him on his firm's enterprise in the field in question. I am sure, however, that our members on this side of the water will be glad to learn that my firm, Messrs. Hadfields, Limited, of Sheffield, produced at a time considerably before the date mentioned by the author large quantities of heat-treated alloy-steel castings of important nature. The Terre Noire Company had also done this at a still earlier period as regards carbon-steel castings, generally using oil for their toughening baths.

Unfortunately I cannot attend the meeting, to be held in Leicester, to present this information myself, but have much pleasure in sending copies of the photographs described below showing some of these Hadfield heat-treated steel castings, typical as they are of many other applications of similar products. They are, too, of interest as showing how *cast* products of steel can in many cases, and for certain classes of work, be made practically equal in toughness, soundness and other qualities as compared with forged steel, and at less expense.

Photograph Fig. 4 represents a *cast* ammunition tube, of "Era" steel, weighing 16 tons, made by Messrs. Hadfields, Limited, in their large steel foundry. This was supplied to His Majesty's Government in 1905, and tested a few months afterwards; the extraordinarily satisfactory results are well brought out by the photograph.

The other photograph, Fig. 5, shows a casting of "Era" steel in the form of a gun shield, weighing 10 tons, also supplied by the same firm to His Majesty's Government in 1908. The excellent manner in which this stood the severe tests shows the high quality of this cast material.

Such tests are probably the most severe to which steel, whether cast or forged, can be submitted, that is, the attack of gun fire. In the case of the ammunition tube, this heat-treated steel casting resisted the attack of 6-in., 7.5-in., and 9.2-in. armour-piercing projectiles fired at velocities up to 2,040 foot-seconds. In the case of round No. 4 at the tube in question, no less than 11,000 foot-tons of energy were expended at this one impact, and the total energy expended on this tube was 50,000 foot-tons.

As regards the gun shield, this successfully resisted the attack of 4.7-in. and 6-in. armour-piercing projectiles fired at velocities up to 2,050 foot-seconds. The striking energy in the case of one round was 2,928 foot-tons, which is equivalent to perforating 10½ in. of mild steel or 8 in. of hard-faced armour.

The yield point of such heat-treated nickel-chromium steel is from 30 to 35 tons per sq. in., and the tenacity 45 tons per sq. in.

Heat-Resisting Castings.

Reference is made by the author to heat-resisting castings. We in this country are not behind in this important advance. My own firm alone has already produced large tonnages of such products, including castings weighing up to more than three tons each. I gather from the author's remarks that he considers there is a reluctance in America to make castings of such nature. All I can say is that we over here will gladly execute contracts of almost any size for such classes of work. Moreover, so far, I have not seen many designs of castings submitted to us that we could not undertake, whether in the quality of steel known as heat-resisting or non-corroding.

Conclusion.

In conclusion, I wish our Institute every success in the excellent work it is accomplishing in increasing our scientific and technical knowledge with regard to foundry work of all kinds, with the many metals and alloys which modern invention has placed at our disposal.

AUTHOR'S REPLY.

As the first makers, and still among the leading producers, of 12 per cent. manganese steel castings in the United States, the author's employers, the Taylor-Wharton Iron and Steel Company, share with their good friend, Sir Robert Hadfield, his pleasure in recalling the days, "now many years ago," when they were assisted by him in developing the manufacture and sale of 12 per cent. manganese steel castings in which they were then, and still are, so signally successful. So, too, they recall with pleasure the success that Sir Robert had in England in the manufacture of cast alloy steels for naval work, such as he illustrates in his discussion.

Despite Sir Robert's statements, however, they know of no instance in which steel castings containing manganese from 1 to 2 per cent. were successfully utilised for their strength and shock-resisting qualities prior to the author's pioneer work at High Bridge in 1909. In the higher carbon ranges, to be sure, these steels were utilised to some extent by Sir Robert Hadfield and others for their hardness, but in 1907, when the author was first associated with his uncle, the late Dr. Henry M. Howe, in the development of special steels for the Taylor-Wharton Iron and Steel Company, he found that steels with manganese averaging 1.50 per cent. were universally considered to be brittle. Dr. Howe, who was at all times in touch with Sir Robert Hadfield in these matters, at that time shared this erroneous view. Indeed, Guillet was the first, to the author's knowledge, to recognise the falsity of this then universally held opinion. The following quotation from Guillet† makes this clear, and shows that to him belongs the credit for first recognising the great possibilities of the pearlitic and sorbitic manganese steels for resisting shock and fatigue:—

"Of the steels containing about 0.20 per cent. carbon, those of the first class (from 1 to 5 per cent. manganese) possess a tensile strength and an elastic limit which rises slowly with the manganese content, while the extension and contraction of area diminish slightly; these steels show a very great resistance to shock. This point is extremely important, and, to show it clearly, we have broken more than 100 Frémont test pieces. The results obtained contradict absolutely the very widespread opinion among metallurgists that manganese makes steel brittle. We believe we have demonstrated clearly, on the contrary, that manganese makes steel brittle only when it is present in sufficient amount, or better, when the sum of the carbon and manganese is high enough to lead to the production of martensite. As long as the structure is pearlitic, the steel, far from being brittle, is extremely homogeneous and possesses a resistance to shock which one finds only exceptionally in carbon steels."

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† L. Guillet, "Etude Industrielle des Alliages Metallique," Paris, 1906.

Sir Robert is in error in supposing that the author referred to the *yield point* of 12 per cent. manganese steel in the figures he gave, 17.8 to 20 tons per sq. in. as the elastic limit of that material. On the contrary, the figures given are for the limit of proportionality, and were based upon a number of tests of cast manganese steel, carefully made with an Olsen strain-gauge type of extensometer, reading to 0.000066 in. In the author's opinion, no well-marked yield point has ever been shown to exist in careful tests of cast 12 per cent. manganese steel. The curves showing tests of manganese steel, in Sir Robert's figures 1 and 3 (which, by the way, are of steel containing 0.88 per cent. C., while normal manganese steel contains some 1.20 per cent. C.), in so far as they show anything, illustrate the fact that permanent set began at a figure of some 10,000 lbs. per sq. in., and that no well-marked yield point occurred. The author's carefully conducted tests show the limit of proportionality of this steel in tension to lie between 16.7 and 21.7 tons per sq. in., while the limit of proportionality in compression is much lower, some 9.4 to 12.8 tons per sq. in. These tests also showed the impossibility of locating a definite yield point in either tension or compression.

Limitations of Manganese Steel.

Sir Robert inadvertently misquotes the author when he puts into his mouth the words "he states that these (the explanations of the work-hardening nature of manganese steel) were not *known*, *defined* or *understood* until some fifteen or twenty years ago." The author's statement was (and still is) that "only during the last ten years has it been *generally recognised* that heavy pressure or pounding must be associated with the abrasion, if manganese steel castings are to develop their full power of resisting wear." There is an enormous difference betwen having a thing "known, defined and understood" by experts such as Sir Robert Hadfield and Prof. Osmond, and having it "generally recognised." The author is well aware that Prof. Osmond gave the explanations in question, but he is also even better aware that all the makers and users of manganese steel castings, for many years afterward, utterly disregarded the obvious conclusions to be drawn from Osmond's observations, and repeatedly endeavoured, often at great expense and loss to their customers and themselves, to utilise 12 per cent. manganese steel castings for classes of service to which they were quite unsuited. In 1907, sixteen years after the first manganese steel was made in the United States (High Bridge, N.J., October 29, 1892), and while the Taylor-Wharton Company was still working in close co-operation with Sir Robert Hadfield, the author found their recognised and proclaimed policy to be to try 12 per cent. manganese steel first for any type of service involving wear for which it might be proposed. In the twenty-one years that have since elapsed, the author has been largely instrumental in influencing his own company, their competitors, their customers, and the engineering public in general, to recognise the limitations of manganese steel with regard to the kinds of service to which it is suited, and not to attempt its use where it does not give a good account of itself. In conducting this campaign of education, the Taylor-Wharton Company long ago discarded their former policy of publishing as little information as possible about 12 per cent. manganese steel, especially about its demerits, in favour of a policy of spreading as broadly as possible a knowledge of the properties of the steel, its strong points and its weaknesses. Among the latter, as is now quite generally recognised, are its comparatively poor resistance to pure abrasion without cold working, its flowing and spreading under excessive pounding and pressure, and its tendency to fail readily by fatigue at comparatively low stresses. Some of these facts, though perhaps, as Sir Robert states, "known long ago" in England, have certainly not been "generally recognised" there, and the author endeavoured in his Paper to carry to the "home of the invention of manganese steel" his widely-prosecuted campaign to bring about general recognition of both the merits and the demerits of this interesting material.

The soundness of this policy of publicity instead of secretiveness has been abundantly proved, not only by the enthusiastic reception that it has met from our competitors and our customers alike, but by the increasingly satisfactory volume of business in 12 per cent. manganese steel that we transact each year.

ALUMINIUM CASTING ALLOYS.

A Review of Recent Progress.

By George Mortimer (Member).

Anyone asked to submit a Paper on progress in the casting alloys of aluminium must almost inevitably find himself tending to sit down between two stools. On the one hand, is an almost limitless mass of technical data, patents specifications, trade advertisements. On the other, the fact that a visit to the despatch department of most of the large jobbing foundries would show little apparent advance to the superficial observer, would indicate, in fact, that the bulk of work going through was being cast in alloys familiar to aluminium founders for the past twenty years.

Engineers as a class tend rightly to conservatism in choice of materials, however embarrassingly progressive they may sometimes be, from the founder's view-point, in the matter of design. The British Engineering Standards Specifications for light casting alloys cater well for average requirements, and the founder is content to supply them to the best of his ability as long as the demand is maintained.

The years since the war, however, have been marked by two definite developments of interest to founders of aluminium. In the first place the demand made on cast light alloys has undergone a complete change, following fundamental changes of ideas in regard to transport. Automobile and aircraft designers lean continually towards higher performances for a given weight, bringing more severe stress and temperature conditions than formerly.

An Ever-widening Field.

The rapid expansion in road transport has in itself introduced new problems in regard to maximum seating or freight capacity for a given axle-loading, and the same line of thought is influencing our railways. The marine engineer has entered the field with his demand for alloys resistant to corrosion. Aluminium castings are finding their way into all sorts of unsuspected byways of industry, each with its own peculiar problems to be solved by the metallurgist or the founder, or preferably by both.

The second development is a natural corollary of the first in that demand creates supply. Industrial demand for alloys of special properties has resulted in an overwhelming array of new specifications, and in an immense expenditure of printers' ink, so that the average busy man finds it difficult to see the forest for the trees. In addition to the B.E.S.A. alloys there are many proprietary alloys employed in this country, whilst in America there are at least fifteen or sixteen different alloys of zinc, copper, nickel, tin, manganese, magnesium, silicon, etc., in all sorts of combinations, in current use. In what direction or directions lies the progress?

The reply to that is rather easier than it looks because of one quite simple point. The range of physical properties obtainable by alloying aluminium with other metals appears to have quite well defined limits. All the above alloys when cast in standard chill moulds would give tensile strengths within the range of from about 9 to 13 tons per sq. in., with from 2 to 6 per cent. elongation. It is possible that if the whole list were melted down together these properties would not greatly alter, and it is certain that the existence of fully fifty per cent. of them is unjustified by any property of peculiar value either to the engineer or the founder.

The real progress of the past ten years lies not so much in the discovery of new alloys, as in methods of dealing with them after they are alloyed. Aluminium-silicon alloys pre-dated pure aluminium, but it is only during the past few years that the process of "modification" has been deliberately applied to them on a commercial scale, with effects on their physical properties of far-reaching importance. The very first "aluminium" produced commercially in this country was an aluminium-copper alloy, but many years were to elapse before the mechanism of heat-treatment was studied and applied to this simple group, resulting in a material like duralumin. Practically all real progress of interest to founders, therefore, can conveniently be considered under very few headings, as follows:—(a) Purification of melts; (b) heat-treatment; (c) modification; and (d) protection.

PURIFICATION.

One of the most illuminating pieces of work on this subject, and the one of most immediate use to founders, was the Paper read by Mr. S. L. Archbutt in 1925. All aluminium founders have experienced that insidious trouble known colloquially as "speckled metal," a pinholed appearance that shows up at a machined surface and spoils an otherwise good casting. (See Figs. 1 and 2.) The difficulty in regard to this type of defect is its erratic appearance and disappearance in phases throughout a foundry. Whatever care may be taken in purchase or melting of materials, whole batches of castings can be affected one week, whilst castings may be produced for several ensuing weeks without the defect, and without any apparent change whatever in methods or stocks of metal used.

In ordinary commercial work this defect has been regarded as unsightly rather than serious, but with the growing necessity of the aircraft industry for castings as solid and sound as metallurgy could make them, this long-known trouble began to assume a greater significance.

Archbutt showed that the difficulty was due, not so much to dirt or dross or complex inclusions† but to dissolved gases, mainly hydrogen. Aluminium tends to absorb gases into solution with a readiness diminishing in the following order:—Hydrogen, coal gas, carbonic acid, sulphurous acid, oxygen, air, carbon monoxide, nitrogen, the last-named being for all practical purposes insoluble. Gas tends to come out of solution when the metal is allowed to solidify slowly. Thus, if a heavy section of a casting is heavily chilled a fine machined surface is obtained. If instead it is fed with a large riser, it solidifies more slowly, and gas comes out of solution only in time to be caught and held in the solidifying metal. Hence the porous appearance. Carrying the idea a little further, if cooling were so slow that gases not only came out of solution but also had time to leave the melt, then the metal might be freed of much of its gas content.

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† "Journal Institute of Metals." 1925. No. 1.

The essence of the Archbutt method, therefore, lies in allowing the metal to solidify in the melting pot, and immediately on solidification to bring it up to the pouring temperature again. A refinement consists in assisting the released gases free of the melt by passing a stream of nitrogen through during the cooling process. The effect of this can be seen at once by the intermittent burning of a typical hydrogen flame at the surface for several minutes after turning on the nitrogen.

This discovery, for it amounts to no less, has been of genuine service as affording a logical explanation of a difficult and illogical phenomenon. In the author's experience neither the pre-solidification nor the passage of nitrogen through a melt offer any practical obstacle in foundry routine. The special castings for which such refinements are needed command a special price, and the chief consideration is whether that price is justified in practice by consistency of results. In practice the method certainly results in sounder work in the case of "Y" alloy and the modified silicon alloys, of which more hereafter. In the case of the copper and the copper-zinc series results are more erratic.

It is of interest to note that concurrently with Archbutt's work at Teddington, similar research for the British Non-Ferrous Metals Research Association was producing similar results in regard to copper, in the hands of Mr. Prytherch, at Swansea. In the light of these researches and subsequent practical experience on a routine foundry scale, it would seem that much of the trouble assigned to ingot aluminium may, in fact, be due to the alloying medium. Sections in a good grade of commercial aluminium may be cast in sand, and show, on machining, no trace of pinholes. Some of the same ingot may be alloyed with copper and at once show the typical pinholed appearance. It seems that other metals may introduce a detrimental amount of hydrogen or other gas into a melt, or alternatively act in some manner as a releasing agency for gases already in solution.

The Archbutt Method.

Be that as it may, in applying the Archbutt method the author finds that from the practical standpoint quite as good results may be obtained in the case of copper alloys by treatment of the 50-50 hardener only. It is further suggested that omission of the nitrogen treatment results in no very apparent difference in results, and in practice may be an advantage because of the ever-present possibility of continuing the stream of gas too long in a solidifying melt; entangled nitrogen can cause just as much porosity as precipitated hydrogen. The reduction of the process

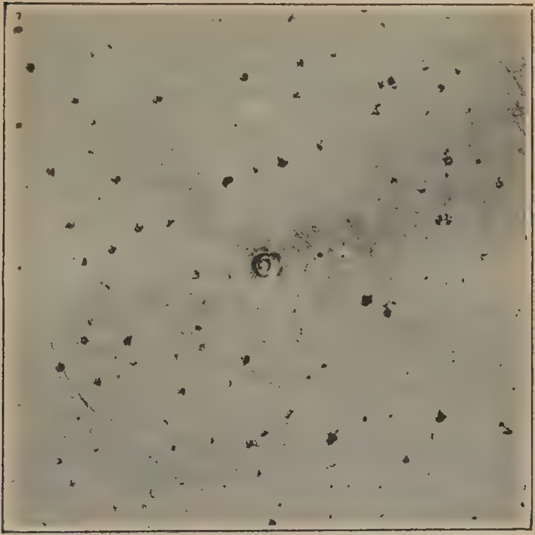

FIG. 1.—SELECTED EXAMPLE OF PINHOLING IN 3L11 ALLOY. SAND CAST IN HEAVY SECTION.

to a simple one of pre-solidification of the relatively small 50-50 melt brings it more nearly into the realm of practical politics. The treatment of a 1,500-lb. melt of the final alloy is far more costly, since in the author's experience it may take two hours or over to solidify in the pot.

Erratic results from this pre-solidification process may be due, not to failure of the method as such, but to extraneous factors. It is possible to remove all gas of practical detriment, and to contaminate again on re-melting owing to exposure to furnace gases. It is possible to remove hydrogen, and yet to obtain in the end a pin-holed machined surface through entrained air, brought in by undue stirring of the melt, splashing during ladling, turbulence in entering the mould. It is quite possible to pour out a sheet of academically-clarified metal on to a flat sand surface, and to get speckled castings

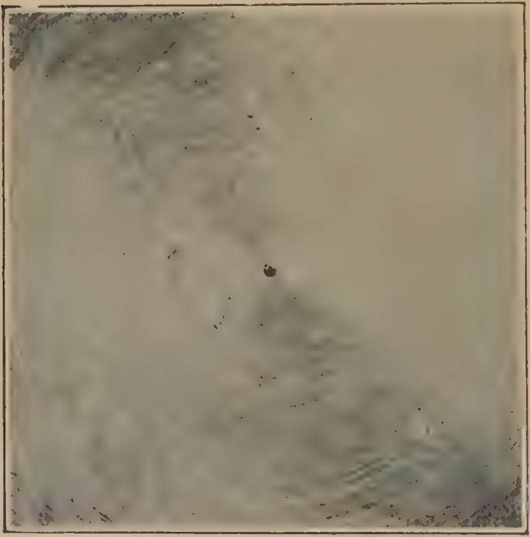

FIG. 2.—SPECIMEN FROM THE SAME MELT AS FIG. 1. TREATED WITH CHLORINE GAS BEFORE CASTING INTO THE SAME MOULD.

every time through gases released from the sand and caught in the solidifying metal. All these pitfalls cannot always be avoided, but to get the most consistent results from the Archbutt method the writer recommends certain precautions.

Desirable Precautions.

(1) Plumbago crucibles at high temperature appear to offer little resistance to the passage of furnace gases. Use an iron, Perlit, or Nichrome pot, thoroughly dressed with an aqueous solution of graphite, whiting and water-glass.

(2) Avoid all stirring or disturbance of the melt until just before pouring. Then skim, and stir well from the bottom upwards, disturbing the surface as little as possible. Skim again thoroughly and pour without delay.

(3) Wherever practicable, arrange for transport of the actual melting pot to the mould, and so avoid the great disturbance of ladling or tilting into crucibles.

(4) Arrange for gates which lead the metal down into the mould as smoothly as possible, without right-angle bends or sudden drops.

The above precautions suggest the realm of fine art rather than the atmosphere of the jobbing foundry. High-class aluminium founding, however, has always been an art rather than an exact science. It is doubtful whether it can ever be the latter, but Archbutt's contribution to knowledge is one definite step in that direction; a step which has brought about a standard in light-alloy founding regarded, only two or three years ago, as a frank impossibility.

It is to be observed, however, that such standards are at present only maintained at a relatively high cost, and, secondly, that in spite of the useful lead given by science, we are as yet only on the fringe of a very intriguing subject. If hydrogen alone accounted for pinholes in castings this elusive gas would present sufficient problems for the average working founder, but the evidence goes to indicate that hydrogen is not the only gas involved, and that no gas or combination of gases accounts for all "speckled metal."

Messrs. D. and J. Tullis indicate a useful line of research in patents Nos. 28388/25 and 11221/25, wherein it is claimed that chlorine or its compounds passed through the melt combine with carbon, iron, hydrogen, nitrogen and other deleterious elements. These impurities are brought to the surface as gases, carbides or oxides, resulting in a refined grain and relative freedom from gas cavities in the casting. (See Figs. 1 and 2.)

The growing knowledge of the profound effect of gases on the properties of metals and alloys, and the fact that many enter readily into solution with metals, points to a future when we may not be so anxious to rid our metals of gases, concentrating rather on the introduction of some particular gas which will endow the material with valuable physical properties.

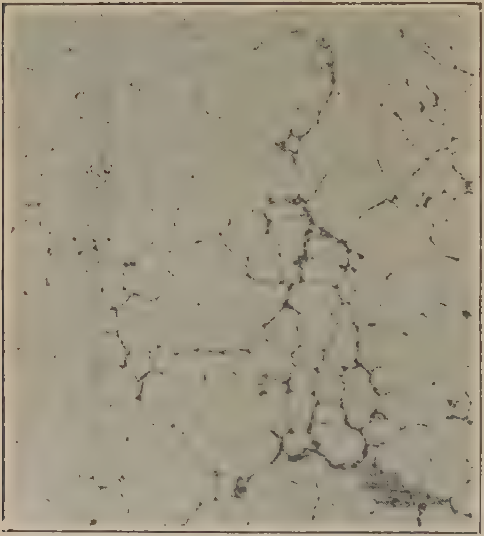

Fig. 3.—4.50 per cent. Copper, 0.32 per cent. Silicon, 0.22 per cent. Iron. Sand Cast. Etch $Fe(NO_3)_3$. × 60.

HEAT-TREATMENT.

The heat-treatment of aluminium-alloy castings is intimately bound up with the question of initial soundness. The principle or mechanism of heat-treatment is the same for all the hard alloys of aluminium, and probably the simplest illustration is that of the straight 4.5 per cent. copper alloy described by Hanson and Gaylor* in 1923.

Reference to the constitutional diagram of the aluminium-copper system shows that copper will go into solid solution in aluminium up to about 5.5 per cent. at 548 deg. C., but that only 1 to 2 per cent. are normally retained in solution at room temperature.

If, therefore, an alloy be made up containing between 4 and 5 per cent. of copper, its microstructure will resemble that shown in Fig. 3, and will consist of primary crystals of aluminium containing about 1.5 per cent. of copper in solution, and surrounded by a network of the hard eutectic compound $CuAl_2$. If the alloy is now maintained for some hours at a temperature of 540 deg. C. much of the $CuAl_2$ network is absorbed gradually into solution in the primary crystals, as seen in Fig. 4. Abrupt quenching at this juncture fixes the excess copper in solution.

The material is now in an unstable condition; it contains more copper than is normal at room temperatures, and the tendency is for that copper to re-precipitate slowly in an extremely finely-divided form. No deformation of a metal can take place without relative movement between the planes of easy slip of the matrix, and the theory propounded by Merica is simply that the presence of fine particles of a hard precipitate causes such relative movement to absorb more work, like grit in a bearing. Therefore deformation of the metal is more difficult. It is "harder."

In practice precipitation is hastened by a low-temperature annealing operation, at temperatures varying from 100 to 200 deg. C. The effect of this series of operations, a "solution treatment," followed by quenching and a "precipitation treatment" may be seen in Table 1.

From the metallurgical standpoint this result is sufficiently interesting, being obtained by a simple thermal process as distinct from hot or cold working. Obviously the field for castings is theoretically broadened at once.

It will not escape the notice of the initiated, however, that the above results are obtained on specimens seldom encountered in routine commercial work. Test bars of even section, cast in chill moulds under most carefully controlled temperature conditions, offer a strong contrast to a sand casting of average intricacy. The one, by reason of its inherently higher physical properties, its soundness and refined grain, offers an easy medium for the inter-diffusion of the solid components of the alloy. The other starts with a handicap of lower physical properties, and it is seldom that the section of the casting, the temperature or the speed of pouring, can be chosen for the best metallurgical results. In the case of the chill-cast bar there can be almost perfect feeding throughout; this also is possible in many sand castings, but the mere presence of a large riser to feed a heavy section brings about a slow local solidification. Slow solidification results in the formation of larger crystals than are ever found in a chill-cast bar, and in discontinuities between those crystals; it may result also in the liberation of gases in the form of pinholes; and none of these conditions conduce to that ready absorption of constituents into solid solution so essential to results.

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* "Journal Institute of Metals," 1923. No. 1.

TABLE I.—*Mechanical Properties of* 4.5 *per cent. Cu Alloy.*

Condition.	M.S., tons per sq. in.	E. per cent. on 2 ins.
Chill cast	10 to 11	10 to 14
Heat-treated for 24 hrs. at 500 deg. C., quenched, and held in boiling water 1 hr.	16 to 17	18 to 25

The net result is primarily that heat-treated sand castings do not give the results obtained on an ideal, chill-cast bar. Secondly, sand castings as a rule call for longer periods of soaking than are required either for chill castings or forgings. There is an alternative in that higher temperatures may be used for shorter periods, but in practice this brings in new difficulties in regard to supporting castings against distortion in the furnace, or against partial collapse in removing to the quenching bath.

The striking possibilities opened up by heat-treatment of the simple copper alloys, however, stimulated the exploration of other compounds which, like $CuAl_2$, decreased in solid solubility with fall in temperature. For example, magnesium itself when added in small quantities to aluminium has little tendency to go into solid solution and reprecipitate. It forms with the silicon impurity always present in aluminium, however, a compound Mg_2Si which behaves much in the same manner as $CuAl_2$. An alloy containing 1.16 per cent. magnesium and 1.02 per cent. silicon gives as sand-cast a tensile strength of about 8.5 tons per sq. in. with 3 per cent. elongation. When soaked for 96 hrs. at 552 deg. C., quenched in cold water and held at 150 deg. C. for 8 hrs., the bars will give 15 tons per sq. in. with 6 per cent. elongation.

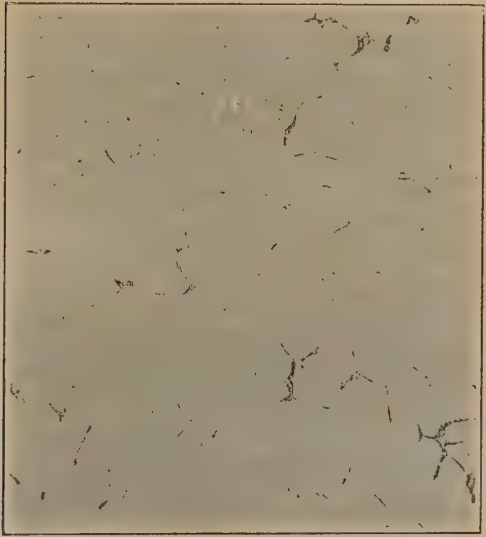

FIG. 4.—4.50 PER CENT. COPPER, 0.32 PER CENT. SILICON, 0.22 PER CENT. IRON. SAME ALLOY AS FIG. 3, BUT HEATED FOR 12 HOURS AT 525 DEG., AND QUENCHED IN COLD WATER. ETCH $Fe(NO_3)_3$. × 60.

Combining $CuAl_2$ and Mg_2Si in the one alloy produces duralumin, an alloy which can be hardened by heat-treatment in the cast condition just as in the wrought. With 4 per cent. Cu, 0.2 per cent. Mg, and with the iron content kept down to 0.25 per cent., up to 22 tons per sq. in. with 8 to 9 per cent. elongation has been obtained on heat-treated sand castings. The addition of a very small percentage of manganese to this class of alloy, copper plus magnesium silicide, does no harm and tends to refine the grain.

In the 4 per cent. copper alloy and its variations it appears desirable to keep the iron content as low as possible: the presence of iron tends to check precipitation, at any rate as far as castings are concerned. The iron content may be made less harmful, however, by the deliberate addition of silicon, forming either an iron silicide or a ternary compound which causes less trouble. An alloy of the 4 per cent. Cu class with 2 per cent. Si added is readily cast and heat-treated, and is becoming known, particularly in its worked forms, under the name of Lautal. Lithium has much the same effect as magnesium, forming a silicide with a solubility varying with temperature: Lithalium and Scleron employ lithium in place of magnesium. The alloy Scleron is almost identical in composition with the familiar 2L5, with the addition of 0.6 per cent. Mn and 0.1 per cent. Li. A number of such heat-treatable alloys, stiffened up with zinc, are in existence and much used in constructional work: the author finds that the weakness of the zinc alloys at high temperatures militates against their wide use in the cast, heat-treated state.

All of these alloys call for somewhat prolonged soaking in the sand-cast state, an economic factor which has encouraged research in the direction of some element which would enable higher soaking temperatures to be used with safety, or would improve the solubility of the hardening compound. An an example, Hyman * has developed an alloy containing Cu, 0.3; Ni, 0.6; Fe, 1.75; and Mg, 0.5 per cent. In the sand-cast bar this alloy will give 16 to 17 tons tensile with 5 to 7 per cent. elongation, after only one hour's soaking

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* "The Properties of Some Aluminium Alloys." H. Hyman, "Jour. Inst. Met.", No. 2, 1925.

at 595 deg. C., followed by quenching in oil. An alloy of this composition might be expected to give a certain amount of trouble in founding, and the very high temperature of treatment may cause difficulty with intricate commercial castings. This, however, remains to be proved: the alloy is worth quoting here as a useful development in the direction of briefer and cheaper heat-treatments. The high treatment temperature is probably made possible by the formation of complex iron-nickel-aluminium compounds, the presence of which raises the solidus. Nickel itself tends to do this, and in addition has the useful property of increasing the solubility of $CuAl_2$. The most widely used heat-treated casting alloy in this country is still "Y" alloy, which, in addition to the usual 4 per cent. copper, contains 2 per cent. nickel and 1½ per cent. magnesium.

"Y" alloy possesses elastic and high-temperature properties which compensate for certain inherent foundry difficulties, and the steadily growing demand for this alloy for parts like pistons, particularly for very large Diesel-engine pistons, justifies a more detailed description of its peculiarities and the foundry methods needed.

Alloying.

Copper is added in the usual 50: 50 alloy, made by melting the required amount of copper and adding aluminium to it a little at a time. Nickel is generally added in the form of shot to form a 20 per cent. nickel "hardener," which is added to the main melt. When using this method of making the hardener there is always the possibility of the nickel shot dissolving away to a pin-point, and then forming with the molten aluminium an almost insoluble compound, which will probably turn up later in the casting as a "hard spot." Hard spots are the bane of "Y" alloy and there are many varieties: if possible it is well to eliminate them seriatim from the start. Several different methods have been devised for the better introduction of the nickel, a good one being the introduction of nickel and copper together. The author has had good results by purchasing a two to one cupro-nickel rod from a reliable source, and stirring the aluminium with it until the requisite amount has washed off it.

Magnesium is added last, and quite simply. Provide a small crucible pierced at the side, and attach it to a stirring rod in an inverted position. The correct weight of magnesium is thrown on the surface of the melt, and is immediately thrust to the bottom by the device described, when it will at once melt and can be stirred in. If it is allowed to rise to the surface it will merely burn away.

Foundry Precautions.

From routine foundry observation "Y" alloy appears to possess higher solidification shrinkage than that common to the other alloys of the B.E.S.A. range, and the effect of this is enhanced by the fact that the pouring temperature for "Y" alloy is often 30 or 40 deg. C. higher than that normal, say, to 3L11. Castings have a distinct tendency to cracks and draws, and to counter this tendency it is necessary, either to feed heavy sections by very ample risers, or to force them to freeze more quickly by using heavy chills. In choosing which method to employ there is only one answer where the castings have to be heat-treated, because the results of the heat-treatment hinge so largely on initial solidity of structure and refined grain. As stated earlier, slow solidification results in excessive grain size and porosity fatal to the best results, and the aim should be to approach the conditions met with in a chill-cast automobile-piston or a test-bar. The further one departs from this ideal the less satisfactory the results, as can be seen in Table II giving average properties after heat-treatment.

This is a point designers might well note. Sections much over ½-in. or ⅝-in. thick in a sand casting might in many cases be split up with advantage. Two well-designed ribs ⅜-in. thick may be stronger after heat-treatment than one section an inch thick.

One other inherent foundry difficulty associated with "Y" alloy is due to the relatively large percentage of magnesium used, a metal notorious for its affinity for oxygen and its sensitiveness to moisture. The formation of magnesium oxide is to be avoided, since it passes into the casting in the form of flakes and drossy lace-work which shows up in small patches on machining. Such patches are not necessarily "hard spots," but they have a tendency to take the finer edge off the keen tools used in modern high-speed machining, and they also advertise themselves as a casting defect and spoil the saleability of the work.

TABLE II.

	Y. P. Tons/sq. in.	M. S. Tons/sq. in.	E. Per cent.	Brinell.
1 in. dia. chill	16	20	4.0	115
½ in. dia. sand	13	16	1.5	107
1 in. dia. sand	12	14	0.5	105

To meet this tendency it is wise to avoid all unnecessary disturbance of the melt once the magnesium has been stirred in. The creamy scum on the surface can be left alone until just before pouring, when it should be removed with meticulous care, the melt stirred with as little disturbance of the surface as possible, and again skimmed. For the best class of work transport the actual melting pot to the mould, and always arrange for gates which cause as little turbulence to the incoming metal as is possible, with no direct drop to the bottom of a deep mould. The writer has found it useful to play a jet of carbon dioxide, sulphur dioxide, or even the flame of an ordinary gas torch into the mould during or just prior to pouring.

It follows from the sensitiveness of magnesium to moisture that all chills should be dry, and it is advisable to keep moulds open until the last moment in the case of green sand, and to keep chills just warm.

One final trouble the founder is likely to meet is also bound up with the magnesium content, and with the difficulty of making castings in any metal which are entirely impervious to penetration by gases during long periods of heat-treatment. If a large sand casting of "Y" alloy is machined up prior to heat-treatment, the machined face will generally show a fine, silvery surface, free of blemish. If another is taken from the same batch and heat-treated and then machined, it will often be found that gases have penetrated an apparently sound and solid casting, and caused the magnesium compounds therein to show up as unsightly grey spots or patches. The presence of such defects appears to have little practical effect on the tensile figures; there are probably minute gas cavities or discontinuities in all castings. The difficulty lies in the fact that magnesium develops such academic defects like the sensitive collodion of a photographic plate and advertises their presence, to the detriment of the sales value of the casting. This class of defect is absent in the case of die castings or heavily-chilled sand castings, and it is possible that it may be entirely eliminated in normal commercial work by using electric muffles for heat-treatment filled with a gas which has no effect upon aluminium or magnesium. If it were possible to cut down the magnesium content or to eliminate it, 50 per cent. of the foundry troubles of "Y" alloy would automatically disappear; but it would then cease to be "Y" alloy.

Heat-Treatment of "Y" Alloy.

The standard treatment for chill castings and for sand castings of fairly light section is as follows:—(a) Soak for 6 hrs. at 510 to 520 deg. C.; (b) quench in boiling water; and (c) either set aside to "age" for at least five days, or retain in the boiling water for one hour.

"Y" alloy, like all the heat-treatable alloys containing magnesium silicide, will age spontaneously at room temperature, given time. The alloys based on $CuAl_2$ only, or with silicon added as in the case of Lautal, do not readily age at room temperatures. This is in some cases an advantage, as heat-treatment and quenching may be done by the founder, and the annealing operation only carried out by the user after the bulk of machining has been done on a relatively soft material.

For die-cast pistons and for small sand castings of light section the period may be cut down materially. Mr. S. Daniels, of the Army Air Service Research Department, McCook Field, Ohio, states that soaking for one hour only at 510 deg. C., followed by quenching in *cold* water and one hour at 235 deg. C., produces in "Y" alloy properties which fulfil the requirements of the U.S.

Air Service Specification 57-72-1. In the author's experience a chill-cast bar 1-in. diameter will give 20 tons with fair consistency after one hour only at 520 deg. C., followed by quenching and normal ageing, and sand castings with sections not exceeding ⅜ in. may be so treated with economy. The longer treatment will, however, always give rather better and more consistent results.

One point of interest to founders supplying castings for use at high temperatures may be mentioned. If instead of ageing at 100 deg. C. the temperature is maintained for an hour or two at from 150 to 200 deg. C., the physical properties *at high temperature* are markedly improved, though the test-bar figures at room temperature may show no change.

For Diesel-engine pistons, which may weigh 600 to 700 lbs. per casting, with sections from 2 to 3 in. thick in the head, soak for a minimum of 48 hrs. at from 510 to 515 deg. C., quench in olive oil, moving the casting slowly up and down in the bath for 30 minutes or so until temperatures are equalised, and allow the casting to age in air for eight or ten days.

Treatment temperatures must be steadily maintained without break or fluctuation; if it is decided to give a medium-heavy sand casting twelve hours' soaking, it must be twelve hours on end; it is fatal to divide the period into two six-hour shifts with an interval between. Reliable pyrometers are essential, but for simple work in foundries not possessing up-to-date heat-treatment plant, much may be done with a bath of fused nitrate of sodium and potassium in equal parts over an ordinary gas burner, which will check sudden rises or falls in temperature.

MODIFICATION.

Developments under this head of interest to the founder are chiefly confined at the moment to the well-known silicon alloys, known in Germany as Silumin, and in this country as Alpax or Wilmil.

The principle of "modification" has been described very prolifically in the technical press in recent years, and many theories have been advanced in explanation. The latest and most exhaustive work on the subject is that of Gwyer and Phillips,* whose theory appears to bear most tests the logical mind can impose. Expressed at its simplest, this theory is that during the process of solidification, whilst particles are passing from atomic dispersion to the crystalline state, they must pass through some point at which the silicon and aluminium aggregates are of colloidal dimensions. If some reagent is introduced into the melt which will check the further coagulation of such colloidal particles, the normal growth of crystals is inhibited. In the case of the silicon alloys the addition of an alkaline metal, an alkaline-earth

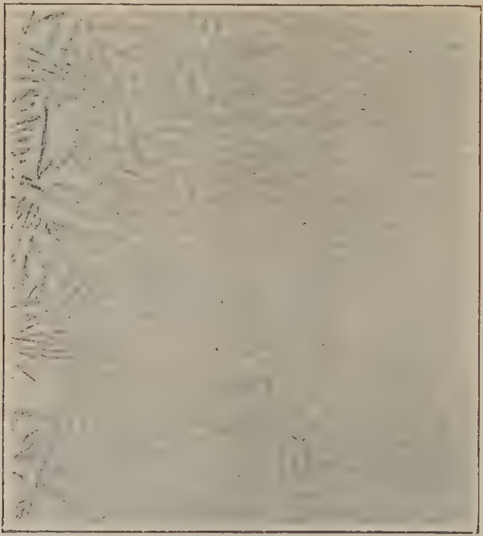

Fig. 5.—13.40 per cent. Silicon, 0.08 per cent. Iron. Chill Cast. Unetched. × 200.

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* "The Constitution and Structure of the Commercial Aluminium-Silicon Alloys." By A. G. C. Gwyer, B.Sc., Ph.D. and H. W. L. Phillips, B.A., A.I.C., "Jour. Inst. Met.," 1926, No. 2.

metal, or their compounds, appears to have this effect of a "colloid protector," and the effect is seen in the micro-photographs (Figs. 5 to 8). The effect on the physical properties may be gauged from the following figures.

If 13 per cent. of metallic silicon is added to aluminium the tensile properties are much as follows:—

M.S. tons per sq. in.	E. per cent. on 2 in.
6 to 8.	0.5 to 1.25.

If before pouring, an alkaline earth metal, such as sodium, be added to the melt, the properties are changed at once to:—12 to 16 tons, with 7 to 15 per cent. elongation.

With these enhanced tensile properties is obtained an extremely refined, silky structure, so that fractures of the modified alloys more resemble those of forgings than castings. The alloy so treated has many other useful features. It is abnormally malleable in the cast state, and castings may be bent and hammered through surprising angles without fracture. It is abnormally resistant to corrosion by sea-water, and it is rather lighter than pure aluminium itself. The alloy can be welded readily without a flux, and the weld zone is generally stronger than the rest of the casting because of two factors. Firstly, the elongation of the material is very high at high temperatures, so that undue stresses are not set up by the local heating and cooling; secondly, the best physical properties are brought out by abrupt chilling, and this is just what one gets in welding a casting, whether it is wanted or not.

It is not too much to say that this development, the work of Dr. Aladar Pacz, is the most important of all advances in light metallurgy in recent years, and although the silicon alloys have been known as long as aluminium itself, the silicon alloy as we know it now is one of the very few new alloys of note produced since the war. Apart from the useful fields in general engineering, and particularly in marine engineering, opened up by the modified silicon alloys, the possibility of applying the principle to other metals and alloys has been demonstrated by Gwyer, and this mere possibility opens up new and attractive vistas for investigators.

Bearing in mind the essential point in the heat-treatment of light alloy castings, the finest grain obtainable, and the difficulty of obtaining a refined grain in large sand castings, the possibilities of heat-treatment in the case of the ultra-microscopic grain of the "modified" structure are of considerable interest. The straight silicon alloys themselves are not susceptible to heat-treatment from the practical standpoint, but the ternary aluminium-silicon-copper alloys are becoming popular, and there is always the possibility that some investigator may evolve a reagent for the modification of "Y" or similar alloys. The addition of small percentages of beryllium has already been mooted in this connection.

FIG. 6.—13.40 PER CENT. SILICON, 0.08 PER CENT. IRON. SAME ALLOY AS FIG. 5, BUT MODIFIED WITH 5 PER CENT. $NaOH$ AT 750 DEG. CHILL CAST. ETCH H.F. × 200.

In practice the use of sodium fluoride, hydrate, and other compounds is gradually giving way to the more convenient metallic sodium, a small percentage of which is wrapped in foil and thrust to the bottom of the melt.

Any founder can cast silicon alloy without apparent difficulty; there is no alloy on the founder's repertoire so free from hot-shortness or any of the troubles normally associated with light alloy founding. The shrinkage is low, and the elongation at solidification point very high; cracked castings are unknown. The metal is remarkably fluid, and will flow into very thin sections, lettering, etc., with excellent definition.

It is equally safe to say, however, that there is no one alloy so likely to let the inexperienced founder down in regard to internal structure, soundness and strength. "Y" alloy has its troubles, but the majority are obvious to the founder before the casting is despatched to the customer. In the case of the silicon alloy the troubles are less obvious; the castings turn out of the mould with a finish and accuracy of definition which will surprise anyone accustomed only to the normal run of light alloys, the usual standard chill-cast bar from the same melt gives high tensile and elongation results, and the castings go forward to their destination, despatched in perfect good faith. If they have been produced in a foundry unaccustomed to this alloy, however, they may have a whole host of hidden defects, ranging from a crystalline, weak structure to cavities the size of a walnut. The content of iron, the percentage of modifier used (which causes trouble either if too high or too low, and which is chosen according to the amount of scrap used, the analysis of the melt, and even the size and design of the casting), the temperature of the melt, the time of pouring after modification, all have their effect on the properties and structure of the casting itself, whatever results are obtained on a chilled bar from the same melt. In no alloy is the accepted standard chill-cast bar so unreliable a guide to the state of things in the casting; it is quite possible to go from one year's end to another passing the acceptance tests with bars which have been cast in ice-cold chills, and with metal on which no modifying agency has been used at all; but the castings in that case would possess very low and unreliable properties. This class of alloy in reality calls for a further check on the actual casting, in the form of a sand-cast section an inch thick, connected to the casting by a ½-in. neck. If the "authorised inspector" broke this coupon off himself, the fracture would indicate the nature of the properties likely to be found in the casting; the fracture must be white and silky, not coarsely crystalline.

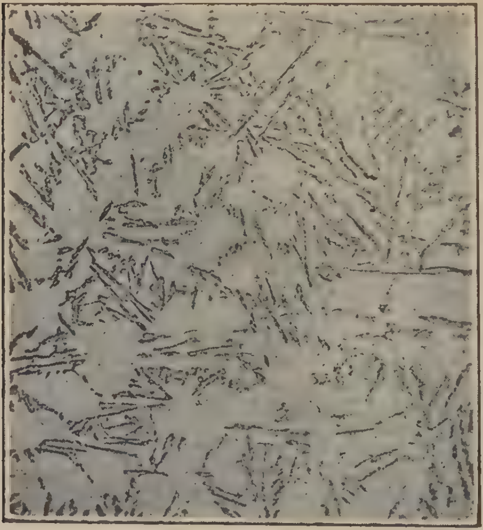

FIG. 7.—9.86 PER CENT. SILICON, 0.45 PER CENT. IRON. CHILL CAST. UNETCHED. × 200.

The silicon alloys as modified are protected by numerous patents, and founders who contemplate adding them to their list of standard products may save much worry and cold cash by acquiring a licence, with which goes much accumulated experience and information. The royalty is the premium one pays for insuring consistent workmanship. and it is probably the cheaper way. It is, at any rate, a way which at once places the novice to this material on a par with those who have borne the burden and heat of the day, and enables him to fulfill his contracts without costly experimentation or anxiety.

The simple addition of silicon to ordinary foundry alloys is one of the useful side issues of the growing popularity of silicon alloys. The addition of from 1 to 1½ per cent. of silicon to any standard alloy has a marked effect on its foundry properties, in reducing the tendency to draws and cracks, and in giving better definition. Every founder knows, for example, the range of troubles associated with a rise in the iron impurity content. If silicon is added to exceed the iron by 25 per cent., this range of troubles subsides, and it

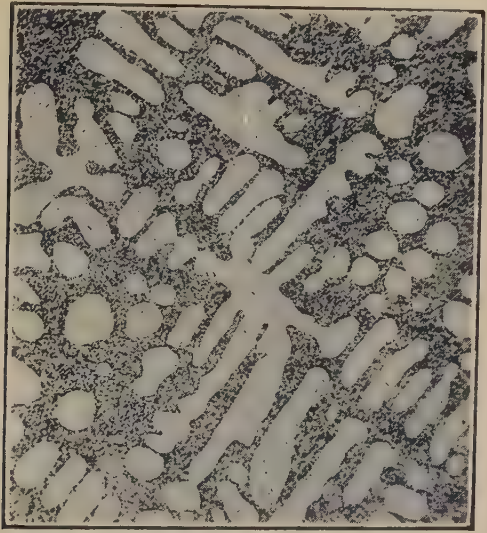

FIG. 8.—9.86 PER CENT. SILICON, 0.45 PER CENT. IRON. SAME ALLOY AS FIG. 7, BUT MODIFIED WITH 5 PER CENT. NaOH AT 750 DEG. CHILL CAST. ETCH H.F. × 200.

becomes possible to use up collected sculls from pots, and other low-grade material, and cast it without difficulty into loud-speaker horns and similar unstressed work.

PROTECTION.

The question of corrosion is nowadays not quite the bogey it used to be, when the standard of aluminium supplied to commerce was not so consistently high, nor its alloying and handling so well understood. There are conditions on seaplane or naval work, however, which call for some protection in the case of aluminium as in the case of iron. There are many paints, collodion lacquers and varnishes which offer good protection as long as the coating is kept intact. Strangely enough one of the soundest protective paints of this class is aluminium paint, long known as a protective against corrosion for such parts as lamp-posts and tramway overhead equipment, especially in sea-board towns. Recently aluminium paint, especially when sprayed on, has been found of definite protective value in connection with aluminium castings.

Lanoline.

It is generally found that in the engine rooms of ships, aluminium castings can be left unprotected, whichever of the standard alloys is used, because of the film of oil always present. Lanoline is one of the cleanest and most tenacious grease films, and castings may be dipped in hot lanoline and wiped down as a preliminary to painting. Castings coated thus have withstood exposure at half-tide with no paint or further protection for ten months or a year.

Sodium Silicate.

If castings are soaked in water glass (specific gravity 1.1) for a couple of hours, followed by baking at 120 to 175 deg. C., they exhibit a marked resistance to sea-water corrosion. This is a good preparation for subsequent painting, and it is one which is applied without special apparatus in the foundry. The process was developed by A. C. Zimmerman and S. Daniels at the McCook Field Research Laboratories, and is known as the "Z-D Process."

Anodic Oxidation.

This is the most effective of all methods of protection, but is itself protected by British Patents Nos. 223,994 and 223,995, and it calls for a certain amount of special apparatus. The process consists in making the casting the anode in a 3 per cent. solution of chromic acid; voltage is slowly raised from 0 to 40 volts in 15 min., and the latter tension is held for 35 min.; it is then raised to 50 volts for five minutes, and the casting is taken out and washed. The result is an extremely thin and tenacious film which for all practical purposes inhibits corrosive action. A dressing of hot lanoline further assists matters, and the film cannot be removed except by sheer mechanical abrasion. Obviously this method is more applicable by the customer after all machining has been carried out, but founders who wish for further details on this and other electrolytic protective devices cannot do better than refer to the Paper by H. Sutton, M.Sc., and A. J. Sidery, Assoc. Met., published in the "Journal of the Institute of Metals," 1927, No. 2.

Spontaneous Protection.

Protective methods so far referred to are deliberately applied, either mechanically or electrolytically. Certain metals and alloys have the property of self-protection by the spontaneous formation of the necessary film. Aluminium itself would corrode with extreme rapidity were it not for the oxide film which instantly forms on its surface Stainless steel owes its stainless record to this phenomenon, and both aluminium-brass and aluminium-bronze owe to the film-forming propensities of aluminium their unique resistance to corrosion. This protective film can be very materially strengthened in the case of aluminium castings simply by baking them in a core oven for an hour or so at round about 180 deg. C., a recent discovery of practical value to founders because of its simplicity and the useful degree of protection obtained.

Attention is being now directed to the possibility of introducing some element into aluminium alloys which will automatically enhance this property. It is possible that silicon has some such effect; castings exposed to half-tide in estuaries have shown little or no corrosion of practical import after over a year's exposure, and their after appearance has much resembled that of an anodically oxidised specimen. Recently the effect of very small percentages of antimony has been studied in Germany, and this is the basis of the K.S. Seawater alloys, of which it is claimed that they spontaneously develop a film of high protective value which is automatically replaced on abrasion.

Summary.

It is hoped that this review will give a fair perspective of the lines on which aluminium-alloy founding has progressed in the past few years, and is progressing now. The author has treated the subject with reserve throughout, because it is recognised that the utmost it is safe to claim is that our feet are set on the path.

Yet, if a true perspective is to be gained of the genuine scientific advancement of recent years it is necessary to go back to the year following the close of the great war. At that time "speckled metal" was regarded as a necessary evil; heat-treatment, as far as castings were concerned, was a laboratory term; neither "modification" nor protection had been heard of. To-day large numbers of melts are treated daily by pre-solidification, and enormous numbers of castings are scientifically heat-treated as a matter of routine. Results do not always tally with those of the laboratory poured and treated bar, and often they cost too much, but they do attain a standard of soundness and strength which on the whole justify the cost. Hundreds of tons of modified silicon-alloy castings are produced on routine lines annually, and large numbers find their way into marine uses in exposed positions. When protection is called for, many founders are in a position to offer it as a matter of routine. It will be seen that the past decade can show concrete evidence of progress, none of which would be obvious to the casual visitor to any modern despatch department.

Visitors not in touch with the industry tend to overlook one very significant point. Only a few years ago quite 90 per cent. of a normal foundry output in aluminium castings went to the motor industry. To-day a normal output may cover an amazing diversity of engineering and industrial interests, whilst designs and scantlings are reduced to a point which, to the discerning, can only mean one thing. Both the materials now available, and the methods employed in their founding, have resulted in the increased confidence of engineers in the capabilities of aluminium-alloy castings for strenuous and reliable service, in competition with materials of inherently higher physical properties.

DISCUSSION.

Mr. H. Milner asked Capt. Mortimer if he had made any tests on aluminium alloys with the object of eliminating "draw," particularly when making such castings as aluminium cast pattern-plates. The pattern-plates the speaker used were 20 to 30 in. square, and had to be cast so clean that they only would require brushing with a wire brush before being put into commission.

The speaker pointed out that he had tried various analyses of aluminium and copper; aluminium, copper and zinc; and aluminium, copper and silicon, for pattern-plates, but had not been able to eradicate traces of "draw," which usually took place in proximity to heavy risers. Finally, he asked Capt. Mortimer if he had had any experience of an alloy suitable for this class of work.

Mr. H. C. Dews, after expressing his gratification at the long overdue interest, as evidenced in the present session, which was being shown by the Institute in non-ferrous foundry work, asked the author for further amplification of the excellent account of gases in aluminium which he had given in his Paper. Was Capt. Mortimer quite sure that the list of gases he had given were soluble in aluminium, or were they combined with the aluminium? On that depended what explanation one accepted of the effect of the nitrogen treatment. The suggestion that the partial pressure due to the insoluble nitrogen released hydrogen from solution was so simple and plausible that it should be considered very carefully. Metallurgical research had provided ample examples of the inadvisability of too readily accepting an orthodox chemical or physical explanation of things. The speaker did not wish to controvert this simple explanation, but merely to utter a word of caution and to press for Capt. Mortimer's views on the matter. With regard to the commercial application of nitrogen treatment, it appeared that ordinary nitrogen in cylinders would be used, and it was not generally known how impure this nitrogen might be. It contained appreciable amounts of oxygen and other gases, and it was worth asking what effect these impurities had on the aluminium. Finally, there was to be considered the commercial side of the process which so far had been sponsored almost entirely by academic workers, and the speaker would be very glad if the author, with his valuable industrial experience, could give them a lead on the commercial aspect of this treatment.

Mr. G. Buchanan inquired as to the best method of recovering the metal lost in the skimmings when melting aluminium.

Archbutt Nitrogen Process.

Mr. Logan regretted that he had not thoroughly read and digested the Paper, but from what he had seen of it, it appeared to be a very comprehensive Paper on aluminium founding, and, no doubt, would be very valuable for future reference. There were only one or two questions which he would like to ask the author. The Archbutt nitrogen process was mentioned as being a method used to eliminate the trouble known as "speckled metal." Was this a practical commercial proposition, because if so, could it not be used in other branches of non-ferrous founding, as, for instance the casting of pure copper alloys?

Then he would like to ask the author if he had any particular pet theories of his own with regard to the "modification" of aluminium alloys. He also noticed that mention was made in the Paper of "Perlit" cast-iron pots for aluminium melting. What was the author's experience with regard to these compared with an ordinary cast-iron pot?

Mr. T. W. Markland asked whether the author could state the cause of aluminium seeming to be very sluggish, which property became intensified as the casting temperature rose; moreover, after casting, the heads appeared to be more liquid at a lower temperature. He desired to know the casting temperature for running castings of $\frac{1}{8}$-in. section and $\frac{3}{8}$-in. section respectively.

Major Athey asked if in the series of tests which were made relating to L.8 alloy, it was found that if the silicon content be increased to more than 1 per cent. there was a big decrease in the tensile strength. For example, in one case where the silicon content was 1.46 per cent., the tensile strength dropped to 8 tons. Was the decrease in tensile strength entirely due to the increase in the silicon content. Was there a definite ratio between silicon content in L.8 alloy, and the tensile strength?

Difficulties with an Alloy for Cylinder Pistons.

Mr. J. J. McClelland said that during the war he was asked to make a die mould for producing air-craft cylinder pistons. A sample casting was supplied to make the mould to, and as it was an easy matter to follow the way the mould had been made for the sample casting, by following the joint lines, he made the mould exactly the same way. The metal to be used in the mould had to be alloyed to a Government standard or formula, and when they tried to pour it into the mould the metal was not fluid enough to run a complete casting although the mould was heated and everything done to assist it.

This failure resulted in an action at law in which both sides employed an analyst, because the maker of the mould contended that he was not responsible for the composition of the metal, and the other side contended the metal was the same as the sample casting that was supplied for working to. Each of the analysts took a part of the casting and after analysing they gave contrary opinions concerning the alloy.

The practical men connected with the case contended that, as the sample casting had gone very dark, almost black, while the new alloy retained a perfect whiteness the two alloys could not be exactly the same. Thus, the case ended very unsatisfactorily for both sides. His point was, as a practical man and not a metallurgist, that it appeared to be possible for analysts to have very widely differing opinions.

Mr. E. J. L. Howard asked whether Capt.

Mortimer had any data of the relative rate of wear of the various aluminium alloys, *i.e.*, the rate of wear on an aluminium alloy moving over a brass or aluminium surface. Would the wear be less than that which took place on a bronze? What were the comparative impact figures, as measured by the Stanton repeated impact test, of the aluminium-copper and aluminium-silicon alloys? Which of the aluminium alloys was the most suitable for resistance to general corrosion and particularly to very dilute caustic soda solution—about 0.05 per cent. caustic soda?

Disintegration of Ingot made from Aluminium Swarf.

Dr. Budgen said it had been mentioned that when melting some aluminium swarf, an ingot which disintegrated after exposure to the atmosphere had been obtained. The material might possibly have been zinc-base aluminium-alloy or had become mixed with some other elements, such as zinc and tin.

No ordinary aluminium-alloy with aluminium predominating was in the least degree liable to disintegration of the kind mentioned, but alloys composed mainly of zinc with a little aluminium, as used for zinc-base die-castings and sometimes erroneously called aluminium-alloys, were under some circumstances liable to disintegration.

With regard to the best method of treating aluminium swarf, it was a matter of prime importance first to see that the material was as clean as it was possible to make it by riddling to remove fine dust, and centrifuging to remove the cutting compound or paraffin used in machining. A small proportion of dirt much reduced the metallic extractions on melting.

For large quantities, melting was quite well accomplished in cast-iron pots, provided they were first coated inside with a wash of whiting mixed with a little silicate of soda to assist adhesion. Salamander crucibles were equally satisfactory for small heats.

The melting pot should be about one-third filled with molten aluminium at about 650 deg. C., into which the fines were rabbled with a cast-iron rabble. The metal should be maintained in a pasty condition, the temperature not being allowed to rise at all high. More and more material was rabbled in until the pot was full of pasty or semi-melted metal.

The crucible was then covered with a tightly fitting lid and the aluminium paste heated up a little, fluxed with about 1 per cent. of zinc chloride, and the dry dusty oxide skimmed from the surface. The metal should then be ingotted and analysed. Care must be taken throughout not to soften the material more than was necessary to agglomerate the entire mass so that oxidation of the small particles of aluminium was largely avoided. Clean dry aluminium alloy chips and turnings would yield from 80 to 88 per cent. of ingot if treated in this way.

Aluminium Pattern-Plates.

Mr. Tyson said that one gentleman asked what was the best alloy to use for aluminium pattern-plates. He took it he meant aluminium plates only. They made a large number of pattern plates in white metal, but, when using aluminium, the best metal they had found was the silicon alloy, containing 8 to 9 per cent. Si. It was possible then, if they had any breakdown with the pattern at any time, to repair it so much easier with that metal than with another alloy, either by burning a piece on the broken part or by welding. With a silicon alloy it was necessary, where one had heavy sections, to put large feeders over those particular parts. It all depended on what these pattern plates were for, whether they were large or small. The L8 mixture for a very small pattern was quite good. The shrinkage, as explained in Capt. Mortimer's Paper, for a silicon alloy was 1 in 96, which was lower than the figure in the other aluminium alloys.

A Member, interposing, said his experience when making aluminium pattern-plates was that they obtained "drawn" places. He was searching for a mixture which, if possible, would not draw, but one which could be relied upon to produce a plate which only required sandpapering before putting into production.

Mr. Tyson could not say that they would get any aluminium alloy which would be free from draws. It was the foundryman's job to overcome that by chilling or feeding. The finish on these pattern plates made from silicon alloy was very good, and came up almost as well as anything a good plate-maker could get, with a finish equal to any of the white metal alloys.

THE AUTHOR'S REPLY.

CAPTAIN GEORGE MORTIMER thanked the Chairman and Mr. Cook and others for the very kind remarks they had made about his Paper, which had been totally unexpected by him. He had not anticipated that the discussion would have taken more than a few minutes; but as it developed it had raised very many interesting points. DR. BUDGEN had dealt with the question concerning swarf, so he would not refer further to that. Mr. Markland had asked whether there was any harm in raising the temperature of a melt to round about 800 or 900 deg. C There was harm, and it was two-fold. In the first place, as soon as the temperature rose above about 740 deg., aluminium absorbed gases quite freely, and also oxidised freely. This would come out in the castings in the usual "speckled metal" so familiar to aluminium founders, and also in relatively brittle test bars with poor elongation. Secondly, there was a drawback to high melting temperatures which was rather a new point. In making a cast it was always desirable that the grain should be as refined as possible, with the smallest possible crystal-size: because the larger the grain the greater the tendency to "draws" and to cracks. It was perhaps somewhat surprising to know that, however low the pouring temperature used, the melting temperature largely influenced the crystal grain size in the resulting casting. Even if a melt was cooled down to the correct pouring temperature, a high melting temperature results in relatively coarse crystallisation. The lower the temperature and the shorter the time taken in melting, the closer and finer the crystal grain. That seemed a very important point, and also answered Mr. Jolley's question as to the desirability of his method of ridding a melt of gases by superheating by some 200 degrees. Undoubtedly this treatment freed the melt of certain entangled gases: also it increased the risk of dissolved gases. If Mr. Jolley's method were used, then the melt should be solidified and re-melted before pouring into castings, when the troubles due to dissolved gases and to coarse crystallisation would be largely neutralised.

Judicious Use of Scrap.

Although virgin ingot was always regarded as the best material, as in the case of cast-iron, it paid to introduce a certain percentage of good scrap, or to re-melt the ingot: it always produced better work, in his experience. In using brand new ingot of a high-grade one got very fine test-bars, but a tendency to "draws" and to cracks in the casting itself, which could be overcome by remelting or by judicious use of the founder's own selected scrap. Mr. McClelland had asked whether any harm was done by introducing a chunk of scrap into a melt to check a rise in temperature. He thought that this was a very satisfactory way of cooling a melt down, because it was quick, and there was one side issue which was not without interest. The cold lump of scrap in falling to the bottom of the pot passed through liquid layers of alloy in turn, which were thereby solidified momentarily and remelted. There was nearly always an evolution of gas which could not be entirely accounted for by expanding gases within the scrap or by volatile substances on its surface. In other words, one had the Archbutt solidification and remelting method momentarily applied, and any effect should be beneficial rather than otherwise. Major Athey had asked whether the silicon content, raised to 1.7 per cent. in L8 caused a falling off in tensile strength. He had never noticed any falling in tensile strength by the judicious use of silicon, but only in ductility, and in L8 the ductility was in any case negligible. If the silicon content were raised to exceed the iron impurity content by 25 per cent., definitely better castings resulted: the iron complex caused "draws" and cracks, and if it could be converted into an iron silicide or a ternary iron-silicon-aluminium complex, it was then in a form which caused less foundry troubles.

Mr. Howard had asked whether there was any available information in regard to an alloy for resisting wear. A heat-treated casting of "Y" alloy, especially when chill-cast, offered the best wearing light alloy in the writer's experience, and was actually in use for the camshaft bearings of certain aero engines. He would not recommend any other alloy at present for this class of duty. He thought the question was largely one of the price the job would stand: heat-treated "Y" alloy was relatively expensive, and some of the high-copper alloys had excellent reputations for hard-wearing service, as witness the millions of L8 pistons in use. If, on the other hand, one merely wanted an alloy which would withstand knocking about, then the silicon alloys should be considered, because it was very difficult to crack up a silicon alloy casting or knock a piece off it. The silicon alloys, as modified, were remarkably malleable, particularly in the case of die castings: it was a very strong and useful material.

Machining Speeds of Aluminium Alloy Castings.

Mr. Gardom had asked what was the machining speed of aluminium alloy castings. Some loose terms were freely used in regard to these speeds, and it was claimed that these alloys could be machined at 1,000 feet per min., without any statement as to the depth of cut or rate of feed. It was always difficult to get actual facts from a customer, but there was no doubt whatever that these alloys could be machined at speeds far in excess of those possible on cast iron or brass. There was no doubt that cutting speeds of 1,000 feet per minute were used, and that the higher the speed used the better the finish, given reasonably light cuts and light feeds. It was a remarkable sight to see a large aeroplane engine crankcase being faced throughout its length by a high-speed fly-cutter within a few minutes. The only practical snag he had encountered in machining of aluminium castings was when, after supplying for a long period large numbers of L8 pistons, he had persuaded the customer to take heat-treated castings giving twice the Brinell hardness. These heat-treated pistons had gone straight into the routine machines with speeds and cuts normal to L8 of half the hardness, and the customer had been surprised because the fine edges of the tools "went west." The trouble was assigned to "hard spots," and the founder lost the job.

Mr. Logan had asked how they obtained nitrogen for the Archbutt treatment. It was obtained in the usual steel cylinders. He (the speaker) was pleased to have Mr. Logan's information as to the possibility of impurities in the gas so obtained: the presence of hydrogen and oxygen would account for a whole host of anomalies observed when using this method. With regard to the nitrogen treatment being a commercial proposition, there seemed to be little difficulty in application. Many of them were familiar with the old-fashioned poling operation, with a green-wood pole. If, instead, one provided an iron pipe, duly dressed with whiting and water-glass, and attached at one end to the nitrogen cylinder by a flexible tube, one could use this pipe as the usual pole. The nitrogen was turned on gently, and there was little ebullition worth the name: the metal was thoroughly stirred by the nitrogen from the bottom upwards and there was an intermittent burning of hydrogen at the surface. The chief objection to the process was the fact that to be really effective it must be carried out whilst the metal was cooling down and almost solidifying, when the bulk of gases was being released from the melt. There was then real risk of nitrogen becoming entangled in the solidifying metal and causing more trouble than it set out to remove. For this reason he himself had abandoned the method.

Experience of Perlit Pots.

Mr. Logan had asked his experience of Perlit pots, and whether he had found any real advantage from their use. As far as he could remember, trial pots lasted twice as long as the ones in normal service, but cost more than twice as much. There was a great opening for the iron foundry which could produce something good as a material in which to melt aluminium. Anyone could be sure of his market who could make a pot which would not readily scale on the outside nor readily go into solution with the melt on the inside, and he hoped that something in this direction might be done through the agency of the Cast Iron Research Association.

Mr. Dews asked whether anyone had actually taken up the Archbutt method commercially.

Several founders used the pre-solidification method as a matter of routine on certain work: there were definite advantages derived. He referred to work on which the present-day standard of acceptance was very high indeed; it was no uncommon experience to receive from certain clients castings which had been neatly sectioned up and polished, and to receive with these specimens a covering letter drawing attention to several pinholes thus disclosed. He was not exaggerating when he said that in many instances these minute pinholes could not be seen with the naked eye, nor could they in some instances be located at all without the assistance of the covering letter. He did not quarrel with high standards of acceptance for this particular class of work, but if such standards had to be met, then one had to try out every possible means of improving the product. In such cases Mr. Archbutt's method gave quite well-defined results and was justified. They had found that there was an even more definite advantage in eliminating turbulence of the metal from the moment it was melted to the moment it set in the mould; as far as turbulence could be eliminated. For example, melting pots were carried to the mould bodily, and vast care taken in the design of the gates so that metal did not fall vertically any distance or meet abrupt changes of direction. If there were undue stirring, splashing on ladling, causing turbulence on entering the mould, then air got entangled; the oxygen, acting on the metal, was converted at once to alumina, the nitrogen remained entangled and caused as much pinholing as did dissolved gases coming out of solution. Mr. Dews later indicated that one was jumping too readily to conclusions in advocating these various methods of clarifying melts. and he entirely associated himself with Mr. Dews' remarks. That was why he had put the case in so reserved a manner. On page 183 he had written that in spite of the useful lead given by science they were, as yet, only on the fringe of the subject, and it was his feeling that much of the necessary development of these useful scientific theories would lie with the founders themselves. He did not think any founder could claim absolute precision yet in producing castings free from pinholes; they themselves would not, but they felt that they were markedly nearer to this than they were three years ago.

Discrepancies in Light-Alloy Analyses.

Mr. McClelland had referred to the great discrepancy that sometimes existed between analyses of light alloys, especially in the case of analysis of one sample as received from opposing camps in a lawsuit. That was in fact a difficulty sometimes. A government department, for example, would sometimes refer to the analysis sent in by the founder with a certain batch of castings and claim that the proportions as ascertained by their chemists differed from those of the founder. The founder would have a check analysis made and find it in order, but to make the matter certain he would send the sample for independent check by some well-known personality such as the City Analyst. The results of this were often even more confusing; the expert's analysis differing widely from both founder's and customer's results.

Mr. Harley had referred to the value of distributing gates, and he was entirely with him. A large runner might be split up into many small sprues, carefully distributed throughout the casting, with great advantage in the case of these light alloys. It was common practice at the Mills foundry and at many others within his knowledge.

He was glad to have a member's support as to the practical value of an integral cast coupon in addition to the standard test bar, for checking the fracture of the actual casting in the case of modified silicon-alloy sand castings. Mr. Lambert had pointed out, very pertinently, that it was time something was done to round up the various light alloys, of which there were now literally hundreds. In a large foundry working on a great variety of patterns and using, as they were, eight or nine different alloys, all having the same colour and appearance, the practical difficulty of tracing scrap and spillings back to their correct bins, without getting them mixed, was a very real one. It was done year in and year out with success, but only by very close organisation. When in addition one received small orders in some special mixture of no very special properties, it caused much trouble for no practical advantage. It was peculiarly irritating, for example, to receive, as they did time and again, an order for about twelve pistons in an alloy containing zinc. Zinc is not suitable for pistons or other high-temperature work, and it was up to the Institute of British Foundrymen to use their influence in the direction of educating customers in these matters, and to do what they could to steer the public into using only the B.E.S.A. specifications, which covered the whole field likely to be touched. The main exception was the field of marine castings; he thought the B.E.S.A. had not yet issued a specification for modified silicon-alloy castings.

Test-Bar Specification Employing a Chill-Cast Test-Bar.

Mr. Jolley had asked who was responsible for a test-bar specification employing a chill-cast test bar. On the face of it, this did seem rather absurd as a test for sand castings, and we were the only people in the world who did it; we were even, in fact, rather like the Irishman in the regiment, who said all the rest were out of step. As a matter of fact, however, there was a good deal to be said for the chill-cast bar, and for the following reasons:—One could never say that any test bar really represented the strength of a casting, because the question at once arose as to which part of the casting it represented. Owing to change in direction and section, to intricate core work, local chilling or feeding, castings varied in physical properties throughout their different parts. The British Engineering Standards Association, realising that no test bar could give an idea of the strength of a casting with any accuracy, decided that at any rate their test should definitely indicate the quality of the metal going into the casting. A sand-cast bar might or might not do this; so much depended on the individual skill of the test-bar maker. Some men could make very beautiful test bars in sand from one year's end to another, and others could not. If a man were trained to it, then he might go sick, and the founder might find that all his castings go down on test, though they were as good as before and the metal the same as before. In other words, the sand-cast bar brought in many factors additional to that of the simple quality of the metal. The chill-cast bar aimed at eliminating unknown factors other than the quality of the metal. Considered thus, as a datum line wherewith to compare the properties of different melts or of new alloys, the chill-cast bar appeared to offer a more stable datum line than a sand-cast bar. Once the procedure for casting the bars was standardised, it was difficult to get any serious variation in test-bar results unless accompanied by a definite change in the quality of the melt, such as might be caused by stewing good metal or by taking up iron into solution from pots. That, at any rate, was what was aimed at, and once the general principle was grasped, then it did seem that the chill-cast bar might give a more reliable standard for comparison than the sand-cast; but it had to be admitted that they were the only people who had standardised this class of test bar.

He thought he had replied to all the questions asked, but if any had been omitted he would ask the questioner to write, when he would be pleased to give him a written answer. He wanted to thank them for a most interesting discussion. It had been a considerable surprise to him, as he had not thought that the reading and discussion of the Paper would occupy much more than ten or twenty minutes. He had thoroughly enjoyed the morning and their remarks, many of which had been definitely helpful to him personally.

Vote of Thanks to the Author.

The Chairman (Mr. Wesley Lambert), in proposing a vote of thanks to Captain Mortimer, felt sure, after the remarks of one of the speakers with reference to chemical analyses, that a number of the audience had some doubts as to the abilities of the analytical chemist. Having served as an analyst for a good many years, he wanted to say that it was useless sending a sample of metal to a city analyst unless the city analyst had an assistant who was fully qualified to conduct an analysis of that particular metal. No one would think of sending a sample of beer to a dye works. (Laughter.) They would have to have some understanding in the trade that if a certain firm of repute supplied a casting, and a government department, or any other customer, disputed the analysis, the matter should be referred to another producing firm, with a staff of qualified analysts experienced in that particular metal. The analysis of aluminium alloys had become very complicated, and, therefore, it behoved them more than ever to select a man who was able to handle the reference sample. He thought the Institute of British Foundrymen probably would have to consider that matter before very long, and he was very pleased that the point had been raised. There were many analysts who could make correct analyses of aluminium alloys. It was very regrettable that there should be any discrepancies, but those discrepancies should be of such a minor character as to be of no importance to anyone who could interpret the analysis correctly.

The President (Mr. S. H. Russell) briefly seconded the vote of thanks, which was carried with acclamation.

STUDY OF SHRINKAGE IN AN IRON CASTING.

By Maurice Servais, Graduate of Ecole Nationale des Arts et Metiers (Lille) and the Ecole Superieure de Fonderie (Paris).

[French Exchange Paper.]

The purpose of this Paper is to endeavour to examine the process of shrinkage in a grey iron casting. The study originated from a difference of opinion between M. Goujon, the French metallurgist, and M. Ronceray. M. Goujon has written a book in which he gives an account of experiments made by him on the subject of shrinkage. He constructed a frame as shown in (1) of Fig. 5, in which the thin parts A varied in thickness from 5 to 30 mm., and the thick parts B measured 40 mm. On this point he wrote as follows:—

"In these castings certain very curious anomalies occur which would tend to show that it is the thin parts that have the least shrinkage." He adds: "If the shrinkage had taken place normally the parts A ought to have diminished in length much worse than the parts B, and consequently would have caused the end-pieces to bend inwards according to the dotted line or to break under the process of shrinkage, leaving a space between the broken parts.

"The result was, however, very different; the thin parts were longer than the thick, and were bent by the process of shrinkage, the excess length being in proportion to the diminution in thickness, and the end-pieces C were broken in the mould as shown by the sketch, or according to D. In the case of castings in which the difference in the thicknesses was small, the fracture took place only when the gate was broken off with a blow of the hammer.

"In the thin internal parts the differences in shrinkage were less apparent."

Goujon ascribed these anomalies to the fact that the rate of cooling of the thin parts is in inverse ratio to the thickness; the whole or part of their shrinkage takes place while the larger

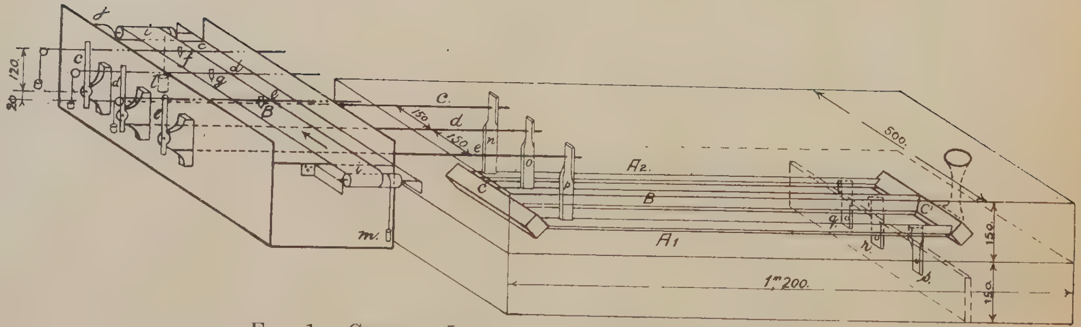

Fig. 1.—General Layout of the Apparatus Used.

thicknesses are still liquid and are capable of feeding those thin parts with sufficient metal to maintain equality in length throughout the system.

In the very important course of lectures conducted by M. Ronceray at the Ecole Supérieure de Fonderie in Paris, this question has been examined, and the distinguished Professor found himself in disagreement with Goujon as regards the mechanism of shrinkage in the experiment described above. He said:

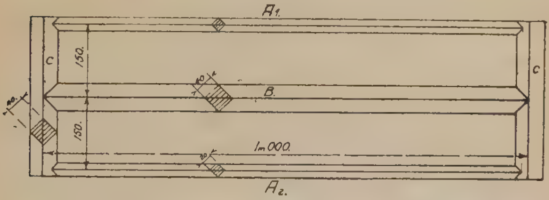

FIG. 2.—TYPE OF TEST PIECE USED. DIMENSIONS IN MM.

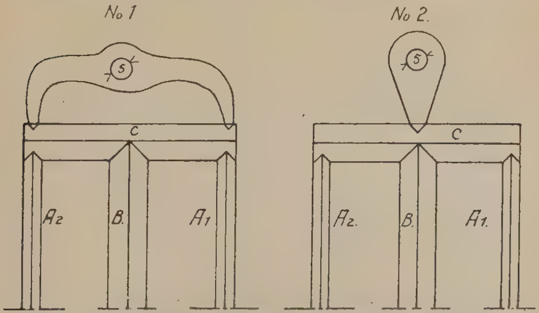

FIG. 3.—METHOD OF RUNNING THE TEST FRAMES. THE ACTUAL RUNNER WAS 25 MM., AND NOT 5 AS SHOWN.

"I do not think what Goujon says is correct; the shrinkage in length, in fact, does not begin to operate until after solidification, and it is therefore impossible to conceive of the thin parts being fed by the thick parts during shrinkage in the solid state. At the most, the liquid contraction might be compensated. We must therefore look elsewhere, and the most reasonable hypothesis appears to me to be the following:—

"The metal when heated must possess—contrary to what occurs when it is cold—a certain property of elongation or of contraction; the solidified thin parts are the first to exercise a tensile stress on the ends of the frames.

"As soon as they have become sufficiently solid and the ends are firm, they act through the frame on the thick parts, causing them to shrink; the latter, being still pasty, yield to this stress, while at the same time the thin parts cool and become firm. The shrinkage of the thick parts then takes place, but it is opposed by the thin parts already cooled. The shrinkage thus creates internal tensions and causes fractures."

It appeared to the author desirable to decide the difference between these two opinions and to determine whether cast iron is capable of elongation or contraction when hot. He therefore prepared a test bar 1 metre in length and having a thickness of 20 and 40 mm. (see Fig. 2).

After a preliminary test the author encountered the same anomalies as Goujon. He was unable, however, to discover what took place after the solidification of the first parts, and he then decided to construct the shrinkage recording apparatus as shown in the general view in Fig. 1, and illustrated in Fig. 7. Its construction consists of the three branches of the castings A_1, A_2, B (Fig. 1), which are fixed to the lower box by means of three iron fittings, q, r, s, bolted on to the bar. These branches are attached by irons n, o, p to the rods of the recorder, which form three amplifying sets, c, d, e (from 1 to 6), actuating three pencils, f, g, h, which record the movements of shrinkage on a common strip, i, propelled by clockwork, j, this band being tensioned by means of the weights l, m. Between the indexes n, o, p, and q, r, s there was a distance of 900 mm.

The experiment was conducted as follows:—The casting, which was green sand moulded under normal conditions, was placed perfectly level, and when the mould was closed the apparatus was placed in position and fixed to the three movable irons, n, o, p. At the moment of pouring the

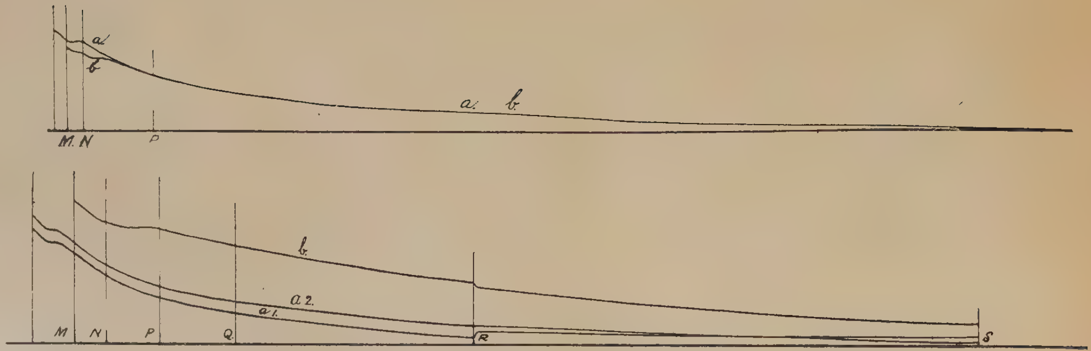

FIG. 4.—CONTRACTION CURVES REGISTERED BY THE APPARATUS SHOWN IN FIG. 7. UPPER CURVE, 1ST TEST; LOWER, 2ND TEST.

apparatus was started and kept in operation for at least two hours. The most noteworthy points of the experiment were carefully recorded.

At the outset the desirability of employing two methods of pouring was envisaged (Fig. 3). (1) Pouring by gate attached to the thin parts is shown at No. 1. The metal introduced under pressure traverses the thin parts before filling the thick bar, so that when the pouring is finished the thin bars are hotter than the thick bars. Fig. 3 at No. 2 shows pouring by a gate attached to the thick bar B. The metal is also introduced under pressure and passes through the thick part before filling the thin bars, so that when the pouring is finished the thin bars, contrary to the preceding case, are coldest.

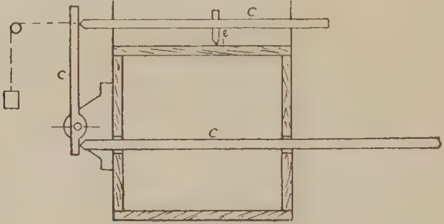

Fig. 6.

First Test.

The greatest care having been observed in preparing the mould, the following results were obtained:—(1) The curves (a) of Fig. 4 correspond to the bars A_1, A_2 and (b) to the bar B; (2) the appearance of the casting was as follows:—(a) There were no cracks; (b) the end-piece C was curved as shown in sketch 2 of Fig. 5, the inflection being 0.8 mm.; (c) the bars A_1, A_2 were curved, showing a deflection of 3 mm., and (d) the bar C, sawn along the line D, showed on cutting an apparent elongation of the bar A_1 of 1 mm.

An examination of the curves gave the following results:—(1) The total shrinkage of the bar B was 6.41 mm. or 7.12 per 1,000. The shrinkage of bars A_1 and A_2 was 7.66 mm. or 8.51 per 1,000. It can be stated straight away that the thin bars

A_1 and A_2, even when the differences in length after sawing are taken into consideration, showed in fact a greater shrinkage than the thick bar B, or, to be precise:—

$$7.66 - 6.41 - 1 = 0.25 \text{ mm.}$$

(2) The shrinkage of bar B began 1 min. 50 sec. after that of bars A_1, A_2.

(3) During the interval M, N (Fig. 4), *i.e.*, 2 min. 40 sec., bars A_1, A_2 underwent no shrinkage, while bar B shrank 0.33 mm. in the same time. It may be said that the shrinkage of bar B is impeded by the bars A_1, A_2, for in this interval of time the fall of the curve b ought to have been more accentuated. It is therefore deduced from this that the thick bar has undergone a relative elongation.

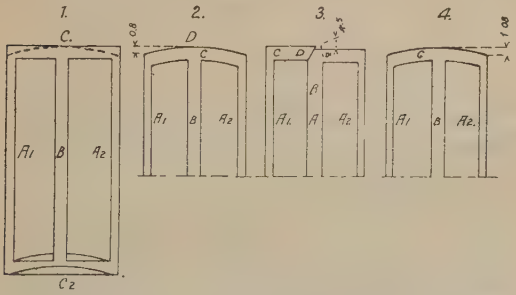

Fig. 5.—Effect of Contraction on the Resultant Casting.

(4) In the interval NP, *i.e.*, for 10 min. 55 sec. the bars A_1, A_2 resume their shrinkage, which amounts to 0.83 mm. more than bar B. It is found, moreover, that the curve b has a sense which is only slightly accentuated. It is now that the bars A_1, A_2 exercise a pull on the frame and cause the end-piece C to bend, making a deflection of 0.8 mm. There is, moreover, a slight but definite shrinkage of the thick bar, as the sense of the curve b is but slightly accentuated.

(5) From the moment P, or 15 min. after solidification has begun, until the completion of cooling the curves a and b coincide precisely. It

is concluded from this that bar B exercises a pull on the frame and causes the bars A_1, A_2 to bend, making a deflection of 3 mm., which corresponds to a difference in length of 0.3 mm. As will be seen, this curvature of the thin bars is purely elastic.

(6) When the casting was sawn a difference of 1 mm. was shown, while the bars A_1, A_2 were straightened. The bars B and A_1, A_2 have therefore been subjected to elastic deformation, elongation and compression respectively for a length of 1 mm. — 0.3 = 0.7 mm.

According to this first test it may be concluded with absolute certainty that M. Ronceray was correct in stating: "The metal when hot is capable of elongation and compression, and even of non-elastic bending." To this the author would add that when subject to lower temperatures the metal is liable to very appreciable elastic deformation.

FIG. 7.—APPARATUS FOR THE DETERMINATION OF CONTRACTION.

Second Test.

The following results were obtained:—

(1) The curve a_1 (Fig 4, 2nd Test, lower diagram) corresponding to the bar A_1; the curve a_2 to the bar A_2; the curve b to the bar B; (2) the casting showed the following characteristics:—(a) The end-piece C was broken along D and cracked along D^1 (Fig. 5, sketch 3); (b) the bar A_1 was straight and A_2 was curved; (c) the break D showed a difference of 4.3 mm.

An examination of the curves indicated the following results:—

(1) The shrinkage of bar B was 11 mm., or 12.22 per 1,000; that of bar A_1, 8.66 mm., or 9.62 per 1,000; that of bar A_2, 9.5 mm., or 10.55 per 1,000.

(2) The shrinkage of bar B began only 6 min. 20 sec. after that of bars A_1, A_2. Here the effect of the difference in pouring in the two tests was clearly apparent. At the moment M the bars A_1 and A_2 had already shrunk 2 mm.

(3) In the interval MN, *i.e.*, in 4 min. 50 sec., the curves a_1, a_2, b are identical; the three bars consequently show the same shrinkage, amounting to 1.66 mm.

From this it follows that the bars A_1, A_2, which are already very firm, exercise a pull on the end-piece C, and cause the movable index of the bar B, which is still partially liquid in the vicinity where the pouring was begun, to be actuated. In reality, therefore, there is a compression of the thick bar, which is a different thing from the feeding of the solidified parts with liquid metal mentioned by Goujon.

(4) In the neighbourhood of the moment N the bar B is completely solidified and tends to effect its shrinkage independently; this is seen in the interval NP where the thin bars shrink 1.08 more than the thick bar. This difference is clearly shown by a curvature of the end-piece C, as in the preceding test (No. 4, Fig. 5).

(5) In the interval PQ, *i.e.*, during 12 minutes, the curves then become identical again. This is because the bar C becomes more and more resistant and has to perform more shrinkage than the others, and consequently pulls on the frame and causes the bars A_1, A_2 to bend, the result being that the shrinkage of the thick part is retarded.

(6) In the interval QR the curves a_1, a_2 are identical, but the curve b is of a different character. The bar B shrinks more. From this it is deduced that the casting no longer forms a rigid whole, and consequently that the end-piece is cracked at D and D^1.

(7) At R there is also a fracture after 1 hr. 3 min., this being shown by the discontinuity of the curves a_1 and b at that moment.

It may therefore be stated that: The bar B was elongated elastically by 0.37 mm., as indicated by the fall of the curve; the bar A_1 was shrunk elastically by 0.5 mm; the curve a_2 did not exhibit any discontinuity, as the cross-piece only cracked so far as the bar A_2 is concerned, but it held.

(8) Between R and S there is no longer any cambering, and each bar effects its shrinkage freely. It will be observed, however, that the bar A_2 has shrunk more than the bar A_1, as it was still in part integral with the bar B. The difference of the shrinkages during this interval gives the value of the difference in the lengths on fracture.

From this test the author draws the same conclusions as previously, viz.: The metal is malleable when hot (temperature near melting point); it is increasingly elastic at lower temperatures and when cold; it is strikingly noticeable that the thin parts are more subject to shrinkage than the thick parts, both in the first and the second test.

Another observation is necessary: In the first test there were shrinkages of 7.12 and 8.51 per 1,000, and in the second 9.62, 10.55 and 12.22 per 1,000. It is therefore thought that in the first case the shrinkages are below the normal and in the second above the normal. One can therefore state that shrinkage may be promoted or retarded according to the method of pouring adopted.

In conclusion, it would appear from this study that a judicious selection of the method of pouring is necessary. It appears logical to begin the pouring of the castings at the thinnest parts, so that these may be fed with the hottest metal in order that the moment of solidification shall be as far as possible the same in the different parts of the casting. In the case of a less simple casting than that which has here been studied, it is well to determine the flow of the metal when the mould is filled.

It may happen—and this is generally the case—that this is not sufficient, and it will therefore be necessary to place heaters over the thin parts or chills over the thick parts. It frequently happens that, without observing it, the tensions are made too great; this occurs when risers or feeders are placed over very thick parts, *e.g.*, in the case of pulleys and flywheels.

In this paper many factors, such as temperatures and chemical composition, are lacking. The author would have liked to submit a more exhaustive study. He intended to make further tests by experimenting with two moulds at once constructed under the same conditions, one of which would preserve the casting intact, and the other would take the casting, which would be cut up to show the various parts immediately after casting. These two castings would be poured together with the same metal, gates of the same form and section being used.

It is hoped in this way to be able to obtain trustworthy comparative data at any moment during cooling.

DISCUSSION.

Dr. A. L. Norbury wrote that he thought the author was to be congratulated on his very valuable Paper. Mr. Servais had set out to solve a certain shrinkage problem, and had done so in a very conclusive and instructive manner. It would have been useful, however, if the author could have given some information regarding the composition of the grey iron; the way it was melted; the pouring temperatures, and so on. He would, however, like to know if there were any signs of chill or white iron at the corners of any of the square test-bars. A considerable amount of data has been accumulated by the British Cast Iron Research Association on the effect of variations in composition, *e.g.*, of carbon, silicon, manganese, phosphorus and sulphur on the solid shrinkage of round test-bars of different diameters. They find, as is well known, that white bars shrink more than grey bars, and that thin grey bars shrink more than thick grey bars of the same composition, and that ordinary variations in chemical composition have little effect on the shrinkage, except in so far as they make an iron white or grey. He thought it had sometimes been assumed that the reason a thick grey bar shrank less than a thin grey bar was on account of a greater graphite content in the thick bar. This, however, was not the explanation, since less shrinkage was found in a thick grey bar than in a thin grey bar of the same chemical composition and graphite content. He would like to know if the author agreed with the following explanation, that in a thick bar the shrinkage of the outside of the bar is affected and lessened consequent on the later solidification and shrinkage of the inside of the bar in a somewhat similar manner to that shown in the author's tests. It was hoped that the author will follow up his very instructive Paper with further investigations of a similar nature.

Mr. Arthur Logan wrote that he regarded this as a very interesting Paper, because it formed an introduction to a subject about which very little was known. He would suggest that a more correct title for this Paper would be "Study of Differential Shrinkage in an Iron Casting." This question of the differential shrinkage in a casting was coming more to the fore every year, due to the increasingly intricate and difficult castings demanded by modern engineering, and Diesel engines in particular. The whole question of shrinkage was really bound up with design, because although a casting of uniform section and design might have as much shrinkage as another casting of unequal sections, yet in the one case the casting would solidify harmlessly as a whole; whilst in the other the rapid solidification of certain parts might prevent the full shrinkage of other parts, with the result that local internal stresses, often of a severe nature, were set up.

He would like to make one practical suggestion to the author which might be of use in future work on this problem. In an investigation into the causes of failure of certain castings which were admittedly of bad design from the contraction stresses point of view, certain experimental castings were designed and made. These were carefully gauged, then a portion which acted as a tie bar was cut through, resulting, as was expected, in a change of dimension. This change of dimension was not only accurately measured, but it was possible to measure the actual stress previously existing, by putting just sufficient load on to bring the casting back to the original gauge size.

Whilst this Paper only touched the fringe of the subject it would be very interesting if the author, or others interested, would pursue this investigation, and provide more information on this very important subject.

Mr. J. Shaw wrote that after reading this interesting Paper giving the divergent views of two well-known French metallurgists, one wonders why no note had been made of a very valuable Paper on the subject by C. Heggie.* From this Paper the point at issue could have been settled at once. The investigation was carried out on much more scientific lines by means of extensometer curves, and those points noted first by each size bar separately and afterwards from the thick and thin bars in two frames cast together. The above is another illustration of duplication of work owing to the lack of a proper summary of all Papers on a given subject.

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* Proceedings I.B.F., 1914-15, p. 66.

IRON FOUNDRY COSTING.

By W. R. Wintle, F.C.W.A.

The subject of Costs, up to a few years ago, was not to any extent appreciated by the practical side of a manufacturing concern. This was owing, not so much to lack of interest in it, as to the inability to understand the nature and form of its makeup. The practical men in those days were not supposed to know anything about the £ s. d. of their shops' trading. They were concerned with output. Those days have gone. Every foreman, superintendent, and manager, is keenly alive in these days to the importance of knowing all they can about the shops they are endeavouring to run, and how much it is costing to run them.

There are many systems and practices in operation all over the country dealing perhaps with this most complex of all costing problems—the foundry. Complex, because, in a great many cases, the design of the place has of necessity had to fit in with a limited capital expenditure, and little thought also to the ultimate outcome of the putting down of a foundry, viz., its products.

On the other hand, there are foundries where every consideration has been given to the production, in separate bays, suitably equipped, of the light casting, the medium, and the heavy type of casting, and costing under these conditions certainly loses some of its complexity. Design then, plays a very important part not only in production, which is its primary object, but wherever method, thought, and science are blended, there also will the cost reveal the true value of the investment.

Cost systems have several uses, and it is not unusual to find in the design of them features which are prone to give more information to one side of the concern than the other. In the accounting or financial department, everything might be quite satisfactory. To the managing director, a little less detail here and there; to the estimating department, efficient recording only; while to the superintendent, foreman, and department manager, more and more detail is necessary. The shops undoubtedly want their data red not, and will welcome any method that provides it. They naturally are not concerned with the higher and executive uses of the information. On the contrary, the higher officials do not want to be overwhelmed with so much detail, but want accurate results assembled in a form, the significance of which they can readily grasp. In fact, the higher the control, the more general becomes the type of information required, but incidentally the grouping and presentation of the facts must be clear and systematic.

One of the essentials lacking in a great many foundries to-day is the "standard cost." The standard cost of an article is either the known "former" cost, or what is the "pre-determined" cost. The form of this information should be so arranged that the actual cost of production can be set alongside as the work proceeds and should always be available to the foreman or superintendent.

In the foundry, as anywhere else, manufacture is the art of making changes in the condition of material by the application of labour and machinery. Involved in that brief statement are the elements of cost—labour, material and establishment charges. Under these three items all the expense of a foundry must come.

Essential to the iron foundry in particular, are the main features of any cost system which is to be of practical value, and these should show first, *direct charges*, as:—The cost of the pattern shop, which is an allied department; the melting department or cupola cost; the moulding shop cost; the coremaking cost; the fettling and cleaning department; the smiths' shop; and the machining and fitting shop (if allied to the foundry).

Secondly, there are the *indirect charges*, such as:—Miscellaneous yard labour and general labour in the foundry; crane driving in the yards and foundry; and pattern carrying between departments.

The materials used, should show the consumption of those for the actual production of castings, such as:—Iron, sand, coal, coal-dust, stove-coke, manure, straw-ropes, blacking, plumbago, chaplets, sprigs, studs, core-vents, core oil, etc., and for the completion of any assembled work in the foundry, direct materials should also be shown, such as:—Jointing material, packing rings, forgings, and steel castings, etc.

Upkeep and Maintenance.—All items making up the running expenses of a foundry should be prominently shown. These include:—Gas for lighting and heating; electricity for lighting and power; steam generated for hydraulic power or crane services; water supply; oils, grease, waste and sundry stores; and box fitting.

Repairs and Replacements should be assembled under the principal items of plant, etc., such as:—Cranes, motors, lathes, moulding machines, blowers, tools and chains, loam mills and mixers, cupola, stoves, and buildings, etc. (See Form No. 5.)

Establishment Charges.

Each business must determine how much or how little the costs shall reveal under this heading, but the more important items are shown under that of "general expenses." Having laid down the particular headings of the information needed, it now will be necessary to follow the method of collection and the routine essential to distribute that information, so that the individual castings, or class of castings produced, may be fairly dealt with for selling purposes.

Various forms are detailed showing the compilation of the data collected, including the monthly cost account. In many foundries only a half-yearly account is considered necessary, but it is assumed here that a monthly cost acoount is prepared, for in competitive days such as these a month is quite long enough to lack knowledge of the results of one's trading, and little time enough to put right the wrongs which have accumulated. It will be worth while to understand, as the outline of the system proceeds, the part which the works in general plays in the building up of the cost, and the foundry in particular. The first of the routine items belonging to the works side of the system is the stocktaking.

Stocktaking.

Physical stocktaking is a matter of prime importance in a foundry. It has been argued that the general methods adopted are loose and carelessly undertaken; the result of which when seen in figures of materials consumed is merely a matter for scepticism. This need not be. A good foreman, and an equally good cost clerk, between them will arrive at conclusions regarding stocks however small or however large they may be, that will be sufficiently accurate as to make no violent differences in monthly comparisons.

All materials on hand on the 1st of each month, whether stored under cover or in the open yard, must be taken into stock, the record being actual weight where possible, and actual quantities if by count. Goods in transit, if the account is being paid in that month, should be added to the stock on the ground. The opposite method is to have returns rendered of everything used during the month and keep a book stock with a physical check at the end of every financial period. This is not sound in practice, because of the liability to render wrong returns and has been known in the case of more than one firm to leave them with large adverse balances to write off in consequence. The true value of their costs, therefore, is lost.

Purchases of Goods Inwards.

The clerk or store-keeper appointed must be held responsible for the receipt of all materials coming into the foundry or for the foundry. Invoices should only be passed on his signature. The date received is very important from a costing standpoint. All other information can be taken from the account itself, as to quantity, weight, price and amount, when once the invoice has been checked.

Wages and Time Recording.

More important, perhaps, than any other record, is that of the wages record. A competent clerk, conversant with foundry practice, regarding personnel and materials is most necessary. Whatever the system of payment, whether contract, piece work, bonus work, or day work, the need of accuracy in booking time cannot be overstressed. Especially where individual jobs are concerned is this a matter for careful supervision both on his part and on that of the foreman. A daily record is essential giving time spent; works order No.; job No.; and quantity made, etc.

As to systems of recording, that is a matter for individual taste and economy. One fact emerges very solidly. Whatever method be adopted, whether time-boards, time-clocks, or time-clerks, the original entry is the basis of all subsequent analysis, and therefore the best means of securing this, compatible with the expense involved, should be the deciding factor, remembering always that there is such a thing as the cost of costing.

Machinery in costing is playing to-day a very important part, and in quite a large number of modern works, where the employees are numbered from, say, 1,000 upwards, the old methods of time records and wages analysis are already considered obsolete. The Powers and Hollerith machines, electrically operated, are installed, and can deal with every day's time in such a way, that the original time booked, being transferred to cards by mean of punches, forms the basis of the weekly pay roll, cost analysis for class cost, job cost, order, or whatever information is required. The new method is undoubtedly costly to instal but undeniably accurate and economical in use.

A most important item of wages cost is that which represents time spent on repairs and maintenance. Too much care cannot be bestowed on the checking of this time, and inside the cost system should be the means of bringing together under the headings already indicated the total cost from all sources spent on repairs. The control of this expense is entirely in the foundry manager's hands, and, in every case where ordinary repairs are contemplated, usually the work is proceeded with only under his direct signature or other responsible official. Especially when times are bad and work is scarce and shops only partly employed will this item tend to increase out of all proportion to the usual figures, very often reflecting the labour which, not being able to book on productive orders, finds its way into the "Standing Orders" or "Repairs Account."

Statistical Records.

A daily charge sheet for the cupola should be prepared giving details of the various grades

FOUNDRY SUMMARY COST. *Month of* , 192

	Tons.	Cwts.
Saleable tons divisor		

	Tons.	Cwts.	Qrs.	Lbs.	Percentage.
Saleable castings					57
Box parts					2
Iron patterns					—
Total saleable					59
Waster castings					7
Tackle and plant					18
Runners, risers, heads, etc., etc.					10
Total Cast					94 per cent.

	Amount.	Total.	Cost Per ton.	Total Cost Per ton.
(1) METAL. Tons. Cwts. Rate.	£ s. d.	£ s. d.	s. d.	s. d.
Foundry pig-iron ..				
Hematite pig-iron				
,, scrap ..				
Cold-blast iron ..				
Steel scrap ..				
Cast scrap (New)				
,, ,, (Own) ..				
Total .. .. = 100 per cent.				
CREDIT FOR WASTERS, RUNNERS, RISERS, AND TACKLE ..				
(2) CUPOLA COST.—Cost per ton of iron melted.				
Wages				
Ganister				
Limestone				
Coke (cwts. per ton melted iron) ..				
Sundry stores, etc.				
Laboratory				
Repairs, etc., as per Schedule ..				
Suspense Account				
Depreciation				
Proportion of power, light, rates, etc. ..				
(3) MOULDING SHOP.				
Wages.—Moulding in dry sand				
,, ,, green sand ..				
,, ,, loam sand ..				
,, ,, by machines ..				
Indirect labour as per Schedule				
Repairs, etc., as per Schedule				
Suspense Account				
Depreciation				
Proportion of power, light, rates, etc. ..				
Materials used :—				
Sand				
Manure				
Blacking				
Plumbago				
Sprigs				
Coal dust				
Cow hair				
Sundry stores, etc.				
Pattern Shop direct Charges ..				
PERCENTAGE OF OVERHEAD EXPENSES TO DIRECT WAGES				
TOTAL PERCENTAGE				
(4) COREMAKING SHOP.				
Wages in Moulding Shop				
,, ,, Core Shop				
Indirect labour as per Schedule ..				
Repairs, etc., as per Schedule				
Suspense Account				
Depreciation				
Proportion of power, light, rates, etc. ..				
Materials used :—				
Sand				
Coal				
Coke				
Straw ropes				
Wood wool				
Core gum				
Core oil				
Rosin				
Wax wire				
Sundry stores, etc.				
PERCENTAGE OF OVERHEAD EXPENSE TO DIRECT WAGES				
TOTAL PERCENTAGE				

	Amount.	Total.	Cost per ton.	Total Cost per ton.
	£ s. d.	£ s. d.	s. d.	s. d.
Brought forward				
(5) FETTLING AND CLEANING SHOP.				
Wages				
Indirect labour, as per Schedule ..				
Repairs, etc., as per Schedule ..				
Suspense Account				
Depreciation				
Proportion of power, light, rates, etc.				
Sundry materials and stores ..				
PERCENTAGE OF OVERHEAD EXPENSE TO DIRECT WAGES				
TOTAL PERCENTAGE				
(6) SMITH'S SHOP.				
Direct wages				
Coke				
Sundry stores				
Iron and steel				
Repairs, etc., as per Schedule ..				
Suspense Account				
Depreciation				
Proportion of power, light, rates, etc. ..				
PERCENTAGE OF OVERHEAD EXPENSE TO DIRECT WAGES				
TOTAL PERCENTAGE				
(7) GENERAL EXPENSE AND ESTABLISHMENT CHARGES :				
Salaries of Manager, Clerks and Officials				
Salaries of Salesmen and Expenses ..				
General Charges (i.e., Directors, Auditors, Law Charges, etc.) ..				
Telegrams, telephones, stationery, etc.				
PERCENTAGE OF GENERAL EXPENSE TO WHOLE OF DIRECT WAGES FOR FOUNDRY = ...				
TOTAL FOUNDRY COST £ FOR UNMACHINED CASTINGS.				
(8) MACHINE SHOP.				
Wages—machining direct to customers' orders				
Wages—fitting direct to customers' orders				
Wages on repair work for Foundry = to repairs Schedule				
Direct materials to customers' orders				
Establishment charges and overhead expense to customers' orders ..				
Establishment charges and overhead expense to repair work (to repairs Schedule)				
TOTAL FOUNDRY COST £, INCLUDING MACHINE SHOP				

STOCK AND PRODUCTION STATEMENT.	Tons. cwts. qrs. lbs.	Rate.	£ s. d.
Stock of castings at beginning of month			
Cost of good castings in current month			
Total			
Less castings in stock at end of month			
Cost of castings delivered during month			

FORM No. 1.—FOUNDRY SUMMARY COST.

of iron used in pig and scrap, coke, limestone, etc., the number of charges, and the quantity of new scrap put on, as against own scrap produced previously (see Form No. 7). The previous day's weight of scrap produced by runners, risers, gates, spare metal, tackle, etc., should also be the subject of a further record, the information having a necessary bearing on the coke consumption per ton of iron melted, and also the loss in melting. A difficulty in doing this is often experienced, and especially in large foundries is this the case. Where the difficulty exists, the loss in melting is not a reliable figure unless it is pre-determined.

Tests can be taken over a period of a week or more to ascertain the loss by (1) keeping a strict record of all iron going into the cupola; (2) after the ladles are lined, weighing them; (3) filling the ladles from the cupola, skim them and reweigh. The difference between each day's weighing into and out of the cupola will represent under normal conditions a fair index to the loss in melting. One could not argue, of course, that the figure so found would be right for all time—much depending on the quality of pig and scrap being used. But assuming the tests covered several periods during the year, then the percentage could be used with reasonably accurate results.

The cupola and production record becomes then a matter of routine with all the factors known essential to good management. Total input minus loss in melting will give total output, and total output minus weighing of saleable castings, wasters and sundry tackle will leave the balance representing the runners, risers, heads, metal over melted, etc. The value of knowing these figures depends on the use made of them. Coke consumption per ton of metal melted reflects on the quality being purchased. The loss in melting will likewise determine some relationship in the quality of scrap and pig purchased.

Another method is to ignore the total output of the cupola and only take the saleable weight of good castings, the wasters and the tackle, and apply a known loss in melting of, say, 6 per cent. The formula for an output of 100 tons would be $\frac{100 \times 100}{94}$. This will give the amount of metal

SCHEDULE FOR DISTRIBUTION OF POWER, LIGHT, HEAT AND WATER.

Month.	Electricity.	Lighting Cost.	Heating Cost.	Water Cost.	Total.	Departments of Foundry.						
						Cupola.	Moulding Shops.	Core Shops.	Fettling Shops.	Smiths' Shop.	Machine Shop.	
Proportion	Where a steady ratio is maintained.					20 per cent.	15 per cent.	5 per cent.	10 per cent.	3 per cent.	47 per cent.	Figures to illustrate only.
January ..	110	25	10	5	150	£30	22½	7½	15	4½	70½	
February	85	23	10	5	123	£24	19	6	13	3¾	57¼	
March ..												
April ..												
May ..												
June ..												
July ..												
August ..												
September												
October ..												
November												
December												

FORM No 2.—SCHEDULE FOR DISTRIBUTION OF POWER, LIGHT, HEAT AND WATER COSTS WHERE DIRECT-METERING IS NOT AVAILABLE.

melted, viz., 106 tons 8 cwt. approximately for the known output of 100 tons, in which case it is assumed that all other metal melted, representing runners, risers, etc., has been duly returned to the cupola and used over again. One can see readily that this is not so accurate as the former method.

Output.

The production record should be for every day's cast, with weights of every casting (after fettling) given, the number of castings made, the job number and works order number. Waste castings to be shown in a separate column, and the cause of waste shown.

Stores Issued.

The issue of materials used in moulding should wherever possible be made from a stores, and charged out on a "used" basis. This will facilitate weekly costing and will also be a check against goods inwards and stock-taking inventories. Other materials, such as sand, coal, coke, etc., must be estimated for any other period less than a month, when the stock book will give the necessary information. Oils, grease, waste, small tools, buckets, bellows, brushes, shovels, belting, riddles, etc., should all be charged against a stores issued ticket. A record of all material used by the smith in the foundry is also essential. The above is to a large extent the works side of the routine of costing. The following pages will deal with the procedure leading up to the final compilation of all the figures relating to one month's trading account.

The Stock Books.

The posting to the stock book of all materials which have been purchased and accounted for is the next step (see Form No. 8). The stock on hand at the beginning of the month is brought forward and entered up under each class of material, such as hematite pig, hematite scrap, foundry qualities, ordinary scrap, sand, coal, etc., etc. To these are added the amounts purchased as per accounts. The totals of stock and purchases are then made, and from these totals the stock

DISTRIBUTION OF LOCAL RATES AND FIRE INSURANCE.

	Estimated Rateable Value. Buildings and Equipment.	Per cent.	Rates.			Fire Insurance.			Total.		
	£		£	s.	d.	£	s.	d.	£	s.	d.
Cupola Department	3,000	3.15	1	3	1	0	1	11	1	5	0
Moulding Shop	35,000	36.85	13	11	0	1	2	0	14	13	0
Core Shop	10,000	10.52	3	17	11	0	6	6	4	4	5
Fettling Shop	1,000	1.06	0	7	7	0	0	8	0	8	3
Smiths' Shop	1,000	1.06	0	7	7	0	0	8	0	8	3
Machine Shop	45,000	47.36	17	8	4	1	9	7	18	17	11
Total	95,000	100.00	36 per month (for 6 months)	15	6	3 per month (for 12 months)	1	4	39 per month	16	10

Form No. 3.—Distribution of Local Rates and Fire Insurance.

DISTRIBUTION OF FOREMEN, Miscellaneous Yard Labour, Compensation, etc.

Month.	Foremen.	Miscellaneous Yard Labour, unallocated.	Workmen's Compensation.	Sundry Supplies, Medical, Ambulance, etc.	Total.	DEPARTMENTS OF FOUNDRY.						
						Cupola.	Moulding Shop.	Core Shop.	Fettling Shop.	Smiths' Shop.	Machine Shop.	
Direct labour					£2,000	£100	£1,100	£200	£50	£50	£500	Figures to illustrate only.
Proportion of total						5 per cent.	55 per cent.	10 per cent.	2½ per cent.	2½ per cent	25 per cent.	
	£	£	£	£	£	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s d.	£ s. d.	
January	130	62	40	6	238	11 18 0	140 18 0	23 16 0	5 19 0	5 19 0	59 10 0	
February												
March												
April												
May												
June												
July												
August												
September												
October												
November												
December												

FORM NO. 4.—DISTRIBUTION OF COSTS OF FOREMEN, ETC.

MONTHLY REPAIRS SCHEDULE, sh

Source of Expense.	Cupolas and Equipment.	MOULDING				
		Overhead and Jib Cranes.	Loco. Crane.	All Buildings and Crane Track.	Tools and Chains.	I M
FOUNDRY:						
Fitters						
Machine Shop						
Smiths' Shop						
Labourers						
Carpenter						
Purchased outside						
Pattern Shop						
Electricians, etc.						

	CORE SHOP.				S	
	Stores and Ovens.	Other Drying apparatus.	Sand Mixers.	All Buildings.	All Buildings.	E A
As above, etc.						

FORM No. 5.—

adings for Repairs to each Department.

		FETTLING SHOP.					
Moulding Machines.		All Buildings	Cranes.	Sand Blast app.	Tumblers.	Tools, etc.	

	MACHINE AND FITTING SHOP.							
	All Buildings.	Lathe No. 2.	Drill No. 19.	Milling Machine No. 14.	Grinder No. 22.	Fitters' Benches.	etc.	etc.

AIRS SCHEDULE.

on hand at the end of the month is deducted, leaving the balance "used." In the case of the iron this should approximately tally with the record issued from the foundry day by day when the total is aggregated.

Before taking the average prices as shown by the stock book, consideration must first be given to the state of the market, whether constant, rising, or falling. If a falling market, then the valuation of stocks should be at market prices and not purchase price.

Analysis of Wages.

The analysing of wages is a very important branch of costing procedure. Comparisons depend on its accuracy, and comparisons reveal many otherwise escaping facts. Under headings of "moulders (dry sand)"; "moulders (green sand)"; "moulders (loam)"; "coremakers," "fettlers" and "cleaners," "labour assisting moulders," "smiths and machinists" (where attached to the foundry the direct labour cost is ascertained, and in this process each job number is taken out). "Cupola tenters" labour, handling materials to the cupola, unloading and stocking iron, and weighing in form another analysis.

The "indirect labour" is mostly composed of "labourers' wages," "mixing and milling sand," "metal carrying," "store-keeping," "cleaning windows," "cleaning up shops," "yard-crane drivers," "overhead-crane drivers," etc., etc. All these are analysed separately.

Repairs and Maintenance.

All classes of labour will be represented in this analysis. It is the usual practice for booking to be against "standing orders" or code numbers, as it is important for a manager to know, not only the total cost of repairs, but on what particular part of the foundry the repairs were carried out. Hence a set of code letters and numbers dealing with "buildings," "cranes," "lathes," "moulding machines," "core-turning machines," "loam mills," "cupola stoves," "compressors," "blowers," "electrical equipment," etc., etc., is required.

With the analysis evolved on the above lines, the week's wages bill will read as follows:—

	£ s. d.	%
Direct wages to manufacture ..		
Direct wages to cupola		
Indirect wages to general labour		
Indirect wages repairs and maintenance		
TOTAL		100%

The summary of wages will then be entered up each week under each job number, and all moulding and other grades of labour under their respective columns, which are totalled and balanced.

Purchases Analysis.

Apart from the purchases of iron, coal, sand, blacking, etc., to which reference has already been made, and for which stock accounts will be necessary, there are other purchases of quite a different kind, which all foundries will need and which are generally requisitioned for immediate use:—"Wheels for crane tracks," "ropes for cranes," "iron for tools," "woodwork for buildings," "bricks," "cement," and "repairs to electrical equipment," etc., etc.

The whole of the accounts relative to the foundry should be entered up in a suitable purchase book, with columns ruled to take stock accounts, repairs and maintenance accounts, etc. There will also be charges for power, lighting, heating, sundry supplies, etc., and these must be allocated to the proper columns.

Nominal Charges.—Where a foundry draws from another part of the works (internal trading), then charges will be received from those departments which are working for them, just in the same manner, and at prices based upon the open market where possible.

Pattern Shop.

Practically the whole of this shop's cost is chargeable against the foundry, and should be allocated as "direct." If any other contracts are being worked for other firms, then of course only that part which is applicable to the foundry should be charged. The pattern shop itself should

Dr.	Amount.	Total.
	£ s. d.	£ s. d.
To OPENING STOCKS: Tons. Cwts.		
Pig-iron (Foundry)		
Scrap iron ..		
Coke (Cupola) ..		
Limestone ..		
Sand		
Coal		
Hematite iron ..		
Coke (Store) ..		
Other materials		
To WAGES:		
Cupola		
Manufacture		
Labour		
Repairs, etc.		
To PURCHASES:		
Pig-iron (Foundry)		
,, (Hematite)		
Scrap iron		
Coke (Cupola)		
,, (Store)		
Limestone		
Sand		
Coal		
Other manufacturing materials		
Materials for repairs		
To STORES ISSUES:		
Oils, grease, waste		
Materials for repairs		
Sundries supplies		
To CHARGES FROM OTHER DEPARTMENTS:		
Electricians		
Pattern Shop		
Carpenters		
Electric power		
Gas, etc.		
To DEPRECIATION		
,, SUSPENSE ACCOUNT ..		
,, RATES, ETC.		
,, GENERAL EXPENSES		
To BALANCE, BEING PROFIT FOR MONTH..		

FORM NO. 6.—FOUNDRY

COST ACCOUNT.

Month of 192

Cr.	Amount.	Total.
	£ s. d.	£ s. d.
By Sales of Castings Delivered to Customers		
,, Sales to Stock not Delivered		
,, Sales to Stock as Stock..		
,, Closing Stocks: Tons. Cwts.		
Pig-iron—		
(Foundry)		
(Hematite)		
Scrap iron		
Coke (Cupola)		
,, (Store)		
Limestone ..		
Sand		
Coal		
Other materials		

Trading Cost Account.

be the subject of a separate trading account, and its charges to the foundry so made that every pattern can be traced and debited to the "castings order" it is made for. By charges is understood wages, material, and shop overhead, with the usual management charges added.

Up to this point the wages and materials have been analysed and classified; stock books have been entered up and the total consumption for the month of the various materials is known. The repairs and maintenance account has also been posted, and it is known also what wages have been spent and also what materials on this account and on what part of the foundry equipment.

Establishment Charges.—The third element in costing is the establishment charges, which will be referred to in detail in the latter part of the Paper. The records gathered in the foregoing remarks are subsidiary to the final cost record, the completion of which can now be made with the wages and materials and establishment charges shown in their application. (See form No. 1 for proper set-out.)

Melting Department of Cupola Cost.

Direct Wages: Cupola tenters; labourers handling iron and fuel; proportion of foremen's wages. *Materials*: Coke; ganister; limestone; bricks; fireclay; oxygen; feeding irons, etc.

Works Overhead Expense.—Repairs and Maintenance : Wages and materials on cupola and cupola equipment as shown by the repairs schedule. *Proportion of Charges for*: Power, lighting, insurance, rates, depreciation, laboratory, compensation, medical supplies, sundry stores.

Moulding Shop.

Direct Wages: All wages of moulders and helpers in dry sand, green sand, and loam moulding; all wages of moulders and helpers on machine moulding; all wages of moulders and helpers in bench or stump moulding. *Indirect Wages*: All labour in or about the shop, sand milling and mixing, breaking runners and risers, delivering castings to fettlers, lining ladles, cleaning up shop, etc.; proportion of foremen's wages and pattern carrying and yard labour. *Materials*: Sand, cowhair and manure, blacking, plumbago, chaplets, sprigs, coal dust, small tools, bellows, etc.

Works Overhead Expense.—Repairs and Maintenance: Wages and materials on boxes and flasks, iron patterns, moulding machines, benches, buildings, cranes, crane track, chains, and tools. *Proportion of Charges for*: Power, lighting, heating, insurances, rates, depreciation, compensation, medical and other supplies, sundry stores, water, etc. *Pattern Shop Charges*: All pattern-making cost.

Core Shop.

Direct Wages: All wages of coremakers and helpers, including core-turning machine workers. *Indirect Wages*: All wages of sand mixers, sand wheelers, oven men, sundry labour in and about the shop, delivery of cores to foundry, cleaning up, foreman, and yard labour. *Materials*: Sand, coke, coal, straw ropes, wood wool, core gum, rosin, core oil, wax wire, iron wire, small tools and core irons.

Works Overhead Expenses.—Repairs and Maintenance: Wages and materials on stoves, ovens, racks, core carriages, sand mixers, buildings, etc. *Proportion of Charges for*: Power, light, heat, insurance, rates, depreciation, compensation, medical and other supplies, sundry stores, water, etc.

Fettling and Cleaning Department.

Direct Wages: All wages of fettlers and blasters, chippers, tumbling, inspection, etc. *Indirect Wages*: All wages of labourers, cleaning up shop, proportion of foreman's wages, yard labour, weighman and castings, store clerk. *Materials*: All tools required for chipping, cleaning materials such as brushes, file card, sand-blast material, goggles, filling compounds, etc.

Works Overhead Expenses.—Repairs and Maintenance: All wages and materials on buildings, weighing machine, sand-blast apparatus, tumblers, etc. *Proportion of Charges for*: Power, lighting, heating, insurances, rates, depreciation, medical supplies, sundry stores, water, etc.

Smiths' Shop in Foundry.

Direct Wages: Wages of smiths and strikers. *Material*: Coke for smiths' fires.

Works Overhead Expenses.—Repairs and Maintenance: All wages and materials on buildings, hearth, anvils, tools, etc. *Proportion of Charges for*: Power, light, heating, insurance, rates, depreciation, compensation, medical supplies, sundry stores, water, etc.

Machine Shop.

Where a fairly large machine shop is attached to the foundry it should be treated as a separate entity, with a separate profit-and-loss account of its own. In most cases repairs are carried out for the foundry, but also many of its machines are engaged in jobbing work for customers' orders.

The method of costing in a machine shop is entirely different from a foundry. The percentage method of pro-rating overhead expenses and establishment charges is no longer acceptable where the machines vary in type and capacity, as they generally do. Every machine centre is a productive unit of a different design and equipment, and represents a more or less constant earning power, in recovering by the machine rate method the total expenses of the shop. The machine shop should, therefore, like the pattern shop, be in a position to charge the foundry for all the work done on repairs and other contracts. It is important to know exactly what part the machine shop is playing in the final result of the foundry. The machine rate method is too involved to be attempted in this Paper, and is really a separate subject altogether, having no bearing on the foundry costing procedure. For the purpose of this Paper it will be sufficient to remark that all the wages, materials, and expenses of the machine shop must be gathered together and regarded as quite distinct from the profit-and-loss account of the foundry.

From the foregoing arrangement of collecting the foundry cost, it will be seen readiy that each department of the foundry becomes in itself a separate cost and capable of close analysis. In estimating, the method is invaluable, being both helpful and instructive in eliminating any charges connected with departments which are not concerned with the estimate. The last feature to be added to complete the cost is the general expense or establishment charges proper, which are not particular to any one department of a foundry, but common to all.

General Expense.

Under this heading will be gathered all those expenses which, strictly speaking, are outside the management control, but which are well known to be necessary in the administration of a company's affairs. Enumerating some of these items, of which the foundry has to bear its due proportion, are:—(*a*) Salaries of manager, secretary, accountant, clerks, time-keepers, etc.; (*b*) directors' fees and expenses; (*c*) salesmen and travelling expensses; and (*d*) telegrams, stationery, telephones, advertising, law costs, bank charges, office upkeep, auditors, and many other lesser charges.

As to how these expenses are presented in the "cost sheet" is a matter for each individual firm to decide.

Basis for Distributing Works Expenses.

More important than the collection of data is the method of its apportionment. A few leading thoughts on this will be instructive and valuable where a system of this kind is contemplated.

Power, Lighting and Heating.—Wherever possible, departments of the foundry should be metered and the actual consumption debited. If no meters are in, the horse-power-hours of the department motors can be used. Light and heat would have to be estimated and apportioned on the basis of the floor space involved.

Date....................

DAILY CUPOLA RECORD.

Metal charged.	Tons.	Cwts.
Pig iron		
Bt. scrap		
Own scrap		
TOTAL		

Coke consumed
Limestone consumed
Castings produced
Loss in melting
Coke consumed per ton of metal melted =

FORM NO. 7.—CUPOLA RECORD.

Where no exact data at all is available, but the cost in money is known, then an estimate drawn up on a fair basis of what percentage is approximately consumed in each department of the foundry can be adopted, *e.g.*, over a period of twelve months' normal working. For instance, cupola or melting department may take 20 per cent., moulding shop 15 per cent., core room 5 per cent., fettling department 10 per cent., smiths' shop 3 per cent., and machine shop 47 per cent. (See form No. 2.)

Insurance and Rates.—Health and unemployment insurance can be charged direct to each department of the foundry because the figures are generally known. Fire insurance and local rates can be charged on the basis of the rateable value of each department. If not known an estimate can be drawn up which will meet the case. (See Form No. 3.)

Workmen's Compensation, Sundry Supplies, Foreman, Miscellaneous Yard Labour, etc.—These items should bear a very close relation to the number of employees, and should be distributed on that basis, the average number employed in each department each month being the divisor. Another method to distribute is by taking the total labour for each department of the foundry and finding its percentage to the total expense. (See Form No. 4.)

Sundry Stores.—Consisting generally of oils, grease, waste, emery cloth, and the many other numerous small items consumed, the basis is actual, by means of a stores issued tally against each department.

Depreciation, Renewals, Replacements.—There is a wide difference of opinion on this debatable subject. Nevertheless, every foundry has it to face, and every foundry will deal with the item in its own way, whatever suggestions are made. That it is real, and calling for attention in many foundries, no one will deny. The causes of depreciation may be briefly stated as follows:—(a) *Use*—that is ordinary wear and tear; (b) *Lapse of Time*—that is plant, machinery and buildings remaining idle for the considerable time, and (c) *Obsolescence*—that is the termination of the useful life of any equipment, owing to the necessary replacement through improvement in design or purpose, and which would make the equipment uneconomical to run on the old lines.

Market Demands.

The demand for a product or commodity naturally calls for a larger output, and this in turn often renders machinery obsolete. All buildings and machinery should be inventoried, and a plant register kept. Rates of depreciation for each department of the foundry should be applied to each part of the equipment, and a monthly charge made against current costs.

Replacements, through any of the causes already mentioned, should be borne by the depreciation account, and should not be chargeable to the current revenue account. Costs incurred in large overhauls, renewals, and heavy repairs should be met by a provision, based on previous experience to keep a fairly level cost per ton. That is to say, charge to cost an amount for each department of the foundry which will form the credit side of a suspense account, and as and when the overhauls, etc., of a heavy nature occur, debit them to this account.

Boxes and Flasks, etc.

Another costing item of expense is that for moulding equipment of a "loose" nature, such as flasks, boxes, iron patterns, etc. These are generally in constant use and just as generally getting broken and thrown into the cupola. Careful watch has therefore to be kept on this expenditure, otherwise the value, from a book point of view, may soon represent a sum of money which cannot be justified, and which becomes very misleading. Repairs and renewals of this type of equipment are properly chargeable to current cost. New boxes, etc., which have to be made should be dealt with by a cost per ton of castings made, being fixed, and revised from time to time, capable of equalising the cost of making this new equipment, less the residual value or scrap value whichever may be the choice or policy of a particular foundry.

General Expense.—The expenditure under this heading is expressed in the "cost sheet" as an amount common to all the departments of a foundry, and as a percentage on the whole of the direct or productive labour of each department.

Job Costing.

The whole of the foregoing record, as seen by reference to the final cost sheet for the foundry's operations, is now the basis for any particular job cost, class cost or tonnage cost which may be wanted. The time recording will have already been done on each job number in compiling the departmental cost, and all that requires to be done now is to open a cost ledger account for jobs required, charging them with all actual expenditure in wages and material, and allocating to them the "works expense" and "general expense" as indicated by the various percentages and rates ascertained in the final "cost sheet."

Stock of materials at........................
Month of................, 19 ..

	Foundry No. 3.	
	£ s. d.	£ s. d.
Stock		
Invoiced—		
Carriage and Wagon Hire ..		
Haulage		
Transferred		
Used		
Stock		

NOTE.—Other headings carried are Silky, Foundry 4, Low Silicon, Hematite Scrap, C.I. Scrap, Sand, Ganister, Coal, Coal Dust, Gas Tar, Prepared Oil and Napthalene, Core Oil, Core Gum, Newbold, Hematite, No. 2, Steel Scrap, Cupola Coke, Stove Coke, Limestone, Manure, Blacking, Sweepings, Straw Ropes, Plumbago, Wood Wool.

FORM NO. 8.—SECTION OF THE STOCK LEDGER.

In building up a jobbing cost system every care should be taken to balance both wages, material and establishment charges with the summary cost. The correct charge for iron used is often slipshod in its application, but with records kept by the foundry office the right proportions of mixtures can easily be worked out for special jobs, instead of taking some average cost per ton.

In dealing with the "on-cost," the following bases will be found equitable and practicable in distribution.

Cupola Cost.—The total cost of the melting department as per summary cost should be divided by the total weight of metal poured, and each job should bear its own proportion according to the weight it represents, both in saleable weight and wasters.

Moulding Department.—Each job will be debited with the actual cost of moulding. The "on-cost" will be distributed at the percentage it represents to direct labour in moulding as shown on the summary cost.

Pattern Shop Charge.—Distributed on an actual cost basis to every job where patternmaking is involved.

Fettling and Cleaning.—Generally it is not possible to book against every job, but where it is possible, this should be done, especially on intricate work. Distribution is otherwise on a tonnage basis.

Machining and Fettling and Smiths' Forgings.—The cost against each job should be on an actual basis. The "on-cost" in the case of the smiths' shop to be at the percentage it represents to the direct labour as per "summary cost." The "on-cost" in the machine shop is allocated by "machine rates," or if the shop is engaged on work of a similar nature, and machines of similar type and equipment, by the percentage method.

General Expense.—Distribution by the percentage rate as per "summary cost" on the *whole* of the direct labour of each job.

Conclusion.

In conclusion, one of the most difficult problems of the foundry is the half-filled shop, and the constant over-head and general expenses. By arranging the cost on the lines indicated one can see the total expense usually required to be borne by each department of the foundry under normal conditions of trade and manufacture. Therefore it will be much easier, when the output falls very much below normal, to know how much should be suspended through lack of orders, so that jobs made during a depressed period should not unduly suffer by comparison with those made during a period of trade activity.

Cost Accounts.—For the purpose of this Paper, the necessary forms of cost control accounts have been omitted, as being only of interest to the clerical side of the foundry.

Trading Cost Account.—As a comprehensive statement of the operations of the foundry, the "trading account" is, in conjunction with the "cost sheet," most valuable, in that it indicates not only the totals of the wages paid, materials purchased, but the stock in detail of all the principal items, both at the beginning and the end of the trading period. On the credit side of the account, the actual sale will be shown, the amount put to stock for orders, the amount put to stock as stock, and the profit or loss. (See Form No. 6.)

DISCUSSION.

Mr. Wintle said, in presenting his Paper on Foundry Costing, that it was particularly gratifying to him, as a member of a kindred Institute, to have that opportunity of exchanging views with the members of another Institute. If one could criticise institutes at all, it was generally in the fact of their insularity and aloofness. To his way of thinking, progress of the right order would surely be achieved in all Institutes by the free exchange of these real and vital issues for which they existed. Therefore, he welcomed that occasion, both personally and on behalf of the Institute of Cost and Works Accountants, as indicative of the interest which was being aroused all over the country in costing as it related to manufacture. As far as possible, he had endeavoured to keep out of the paper the purely cost accounting side, realising the need of the man in the shop as being greater, and to whom the clerical side had no interest or attachment except in so far as it related to the methods employed in getting out the costs.

Before any appreciable progress was made on either side, there would have to be not only mutual, but reciprocal advances, so that on the one hand no accounting principles were violated, and on the other hand the peculiar difficulties of the shop were perfectly understood. The outline of the system presented was not laid down in any way as purporting to represent the only way; but as an indication of the more modern methods which should govern not only our costs but our quotations. The idea was to lead away, or rather out of, the old rut of recognised past habits into the newer and less beaten tracks.

Cupola Costs.

Referring to Summary Cost, and particularly as regards the cupola, one might be safe in assuming that apart from wages of cupola tenders and labour handling materials, plus coke and limestone, not much else had entered into the reckoning when pricing out an estimate, or making up a cost. He was referring to the general run of foundries; but he was aware that there were quite a number which had installed modern methods of costing, and which went into quite elaborate analyses for all purposes. When, however, one considered the cupola cost in its entirety, it was readily seen what a number of other expenses were applicable; such as the burden of its own repairs and upkeep, its depreciation, the proportion of power generated for hoist, blowers, etc., lighting, laboratory, workmen's compensation, rates, insurances and sundry consumable materials.

What was the factor governing cupola cost? The weight of material which was represented by the castings produced. It was surely imperative then, when talking of "cupola cost," that it should be an all inclusive cost; and every casting made should bear its due proportion according to its own weight. How important this became was the more readily seen by contrasting two different types of work. All foundries had encountered heavy, solid castings which called for very little skill in moulding, and not much in time and wages, whilst others met with were very intricate, fragile, "full of cores," that is castings weighing very little for their size, but costing an extraordinary amount in time and wages, where the moulder dared not trust himself to piecework, but had to feel his way, generally with the help of a pattern-maker. There they had a typical case of two extremes. They would see quite plainly that if the cupola cost was whittled down to anything below its true reflected cost, taking in all the factors known to be applicable, then those items of cost which had been omitted would surely have to be borne by the intricate casting, the heavy casting escaping; because it was general practice, after the cupola cost had been dealt with, to spread all other overhead expenses in proportion to wages incurred direct. It should therefore be a first consideration for the weight to stand its proper cost. Incidentally, it would appear that firms who made heavy castings amongst others, and costed their cupola at anything less than the true cost, were selling these castings too cheaply and were not recovering the cost of production. On the contrary, those firms who specialised in intricate work amongst other castings, would appear to be burdening these same castings with more than their share of expense, because the heavier ones had escaped.

Moulding and Core Shop Costs.

It had been said with much force that figures could be made to talk whichever way was wanted. That was quite true. What was needed, however, in every industry was the basis agreed upon by works and offices as to the correct accounting principles to be employed, and then to stand faithfully by those principles in good times and in adverse times, letting the tabulated result govern the policy of the department, never seeking to find explanations through any other way than what the costs of production indicated.

Items 3 and 4 of the Summary Cost related to the "Moulding and Core Shops." There the wages were shown subdivided under four headings, dealing with dry, green, loam and machine moulding. That might or might not be important in the Summary Cost, but it became more so when dealing with individual or job costs. The idea shown there could be extended to showing in the Summary Cost the approximate cost per ton of each of the four groups side by side, that depending to a large extent upon what facilities any particular foundry had for supplying the necessary details of loam, dry-sand, green-sand and machine-moulding work. Carefulness was essential both in analysing wages for moulders and helpers, but more particularly in the case of the labourers and repair workers. The making up of the schedules referred to depended on these analyses, and the apportionments to the various shops would be reflected in the items shown as "Percentage of overhead expense to direct wages," and also that under "Indirect Labour."

Summary Cost Sheet Grouping.

A careful study of the summary cost sheet would make quite clear the intention of that grouping. For instance, the direct wages in the moulding shop were the wages of the first four items. The overhead expenses would be as follows:—Repairs, suspense account, depreciation, power, light, heat, rates, workmen's compensation, etc. The indirect wages of labourers was principally concerned with metal, and should be added on a weight or cost per ton basis. Therefore, one got overhead expenses × 100 direct wage to give the percentage needed. To that was added general expense (item 7), which percentage was arrived at by taking all the direct wages of the moulding shop, core shop, smith's shop and fettling shed, and dividing into the total of general expense— × 100. Assuming the moulding shop worked out at 40 per cent., and the general expenses at 25 per cent., one obtained 65 per cent. as a total. The core shop might work out at, say, 30 per cent., and the general expense at 25 per cent. Then one had 55 per cent. as a total. The smith's shop might work out at 70 per cent. and 25 per cent., a total of 95 per cent. It was then possible to quote for, or cost, cored and uncored castings and give them their proper quota of establishment charges. The smith's shop might only be needed in costs or quotations occasionally, where, say, eye-bolts were made and cast or fitted, or where special tackle was made for a loam-built job. In these circumstances, also, the extra charge could be added. For many years, he had heard drilled into responsible officials the necessity and importance of regulating the fettling shop by keeping it as empty as possible, which sounded somewhat paradoxical, but, nevertheless, it was an unwritten law that for this department to become congested was the sure indication of bad management. The result of such congestion was always without exception seen in delivery complaints. All that was reflected in the cost per ton of fettling. Referring to item 5, they would see wages, fettling, labour in or about the shop, repairs, suspense account, depreciation, power, light, heat, etc., and sundry stores. The wages of fettling divided into the remainder of the expense, × 100, would give them the expense to be added for overheads. He thought costing in the fettling shops should be as direct as possible, that is to say, where intricate work was involved, time should be charged up as incurred, the rest of the general work to be graded so as to give, say, three prices per ton, according to a schedule of weight. That method formed the basis of payment by results to the fettlers, and definitely fixed the cost per ton apart from overhead. It was up to the charge-hand then to keep his shop empty. If he applied for more help it cost no more except in insurance, etc. He knew of firms where time at ordinary rates of wages was set against tons at so much a ton; and if the fettling shed was empty they paid the difference, if not they withheld payment, or carried forward the loss. Obviously the fact emerged that if at the end of a month's trading the castings made, representing, say, 300 tons, were divided into the cost of fettling for the month, the cost per ton would only be true if all the castings had been fettled. He was very much afraid that in many foundries that was hardly the case.

Foundry Design Can Help Costing.

An admirable costing ensued from a carefully planned foundry built in separate bays, and equipped with the correct class of plant and tackle for making different types of castings. If the bays had clearly defined borders, each busy making a different product, then the same rules of procedure could be applied as indicated in the cost sheet, excepting that three cost sheets would be prepared, one for each bay. The types of castings of a small nature, man-handled, etc., would be in one bay; those requiring jib cranes and runways would be in another; and the heavy castings requiring overhead cranes, etc., would be in a third. The cost would be worked out for each bay, and a summary cost of all three made. The jobs made under these conditions would very naturally bear only the burden expended by their particular bay. It had not been possible to show the cost sheet in general the opposite side to form 1; but on that side was gathered a summary of each week's wage bill, the details of the various charges making up the running expenses, such as electric power consumed, gas used, charges for wagon hire, pattern carrying, carriage on sundries inwards, charges from other departments, water charges, stores issued in oils, grease and waste, and many other items, which were all necessary in managing a foundry. The aim of the make-up of a cost summary should be simplicity. Everyone who assisted in the management of a foundry should know how to read it. Everyone there knew how keen buyers were. They took every advantage of the man who made a mistake in quoting, not always by penalising him so much by giving him the order; they were more subtle than that; they held his quotation over the heads of the people *they* wanted to make the castings. Another aspect of that always impressed him when doing a fair amount of estimating himself. A low tender not accepted and the error never discovered led to the assumption. when the same or a similar inquiry came again, that the previous price was too high. Hence the endeavour to quote lower still with a consequent deflated market and everybody suffering, from the workman upwards. It was only natural when work was scarce for the better-placed firms to snatch at anything at any price to keep doors open; but the fact was mainly there that it was primarily due to poor costing or estimating and not to economic conditions entirely, that selling prices reached such low levels. Again, how often did foundries get the wrong type of work through the same cause, with the right foundries wondering where the work had gone. And no one knew the ultimate losses in buying such experience. Therefore, he pleaded for good costing in the first place, and the sending out of estimates that were based on the true cost.

Extra Work Involved.

Particularly would he like to draw attention to the need in engineering works, where a foundry was considered as part of the whole, for a departmental system of costing, as well as a system of job costing. He knew from experience that many regarded the extra work involved from a clerical point of view as a big obstacle, but the fact remained that they did not know whether the foundry paid or not. The fact that a product was on the market at a remunerative price to the whole works did not necessarily mean that the foundry had produced it at the lowest cost. The profit might be all in the machine shop. Many firms believed in a bonus system for foundry officials based on output and cost. With a department cost in force, the best basis was already provided.

They would notice in the cost-sheet arrangement that depreciation had been included as an item of cost. Whilst that was necessary and justifiable, it did not follow that it would always be possible to preserve that reserve fund against the day of its requirements, especially if that plant was in fairly new condition. In bad times it might be found advisable to transfer that reserve to profit and loss account; but that would not be any reason why it should not be provided for. Unless a complete inventory of all the plant in a foundry was properly made, it was unwise to attempt anything in the nature of guesswork for that figure, especially if the firm had keen competition to face. Far better to leave it out altogether than for it to be badly done to jeopardise the prospect of orders.

Box Parts and Plates.

Where loam work was being made, it was usual for special plates to be made, and their cost, less scrap value, charged to the job; invariably they were broken up and sent to the cupola. Where such jobs were being made, care should be exercised to see that the ordinary moulding boxes account was not charged to them also. As to job costs, the value to be derived in taking out those individual costs was not measured by the result as a matter of interest. He attached to those individual histories a much greater value, a standard value. Every foundry should have its departmental cost, the cost of the whole workshop working over a fixed period, as a measure of its efficiency and ability to trade; but equally should it have its jobbing costs over the same period. The department cost might show a loss of £200. The job cost summary would very probably show one that there was a profit on a certain number of jobs totalling £300, and on other jobs a loss totalling £500—a net loss of £200, which must, of course, always balance to the department result. One could thus see how important those results could become. One should put the cost of the job where money had been lost against the estimated cost, and let the comparison light up the result. It was amazing what job costs revealed to those who were really seeking. A carefully built up departmental cost laid the foundation for more detailed jobbing costs, but sufficient had been established in the Paper to enable anyone to follow the trend of the building up of that most important side of the foundry's activities.

Comparativeness Essential.

All costs, to be really useful, must be comparative. To do that in a foundry was not an easy matter, because all the charges of a fixed nature, such as salaries, management, rates and general expenses, and many other works expenses, were fixed under normal conditions of trade. He had no doubt that that question of dealing with normal establishment charges in abnormal times had engaged everyone's attention on the managerial side of industry. In a machine shop, where the machine rate was in operation, the difficulty was simplified and became definable by a very simple calculation. The foundry, however, was a very different proposition, because it had no constant unit, like machines, to build upon, except it be the capacity of its cupolas. However, the arrangement of the cost sheet on the lines he had indicated brought them nearer a solution of the difficulty. One could fix a normal tonnage consistent with the normal standing charges, and say that that should be the standard for comparison. But it was possible that the foundry floor might be full of very large intricate work of a light nature, the total weight of which would not reach normal capacity at the cupola. Yet the wage bill might be higher than usual.

Obviously it would not do, in a case like that, to suspend any fixed charges on a "cupola capacity basis."

Generally he favoured the ascertainment in each department of the foundry, under normal conditions of trade, of the percentage of overhead and general expenses, and in abnormal or depressed periods of trade that percentage should be applied to the direct wages, the difference to be suspended and charged direct to profit and loss account, exactly in the same way as the "idle time," as it was called in the machine shop, was dealt with. One could be sure under that method that comparative statistics would not suffer. One must remember that the percentage method was also unreliable at times, and apt to lead one astray unless one was alive to certain facts. An excess of work of an intricate nature led generally to a higher direct wages bill. With the overhead and general expenses remaining constant, one got a corresponding lower percentage expressed. On the contrary, an excess of a cheap variety of work corresponded to a lower wages bill. With the overhead and general expenses remaining constant, one got a higher percentage expressed. So, then, in fixing the normal, all factors must be reviewed.

Adaptability of the System.

The costing outline in the Paper could be adapted both to malleable and steel foundries with very few alterations. Each foundry could fit its own circumstances into the ideas laid down, and develop them accordingly. In the light castings trade there were more shops or departments to bring into the scheme; but those, too, could find in the outline presented the basis of a sound, practical system which would adapt itself to their special conditions.

Coremaking Costs.

The PRESIDENT, in thanking Mr. Wintle for his Paper and introductory remarks, congratulated him upon the thoroughness with which he had dealt with the subject. In his introductory remarks Mr. Wintle had anticipated many of the questions which might have been put. He would like to point out the great advantage of employing a member of the Institute of Cost and Works Accountants as against an ordinary accountant to advise with regard to what was a suitable foundry costing method. In the course of an interesting discussion at Leicester a few years ago on foundry costing they discovered one system of costing which had been introduced by an accountant to a foundry which carefully took note of all moulders' wages, but all coremakers were included in "sundry labour." That had the disastrous effect of making all jobs with cores comparatively cheap. The foundry owner, after some years, discovered that the particular casting he produced, which, on that costing, showed a very handsome profit per cwt., was actually costing him, when he reckoned the higher pay of his coremakers, far more than he sold it for in coremakers' wages only! It was no use appealing to any specialists in accountancy unless they were fully qualified by works' experience and knowledge. He did not want the owners or executive staffs of the smaller foundries to be scared by the mass of figures put before them. If one just studied them, one would find that, once these figures had been assimilated and one had obtained a summary, the operation had not to be repeated. One must get the total productive cost (what one actually paid the moulder and the coremaker), and the average total non-productive cost, which included the foremen, labourers, and even the furnacemen, if it was a shop which was run on average tonnage and average staff, and did not fluctuate very much in output. Even the fettlers could be included and calculated on a percentage on the moulders' and coremakers' wages. Obviously, the longer a moulder and coremaker worked on a job, the greater would be the on-labour cost. More assistance would be required from the labourers, and more time would probably be taken in fettling a cored casting, so that it automatically took care of itself. If it was not quite an accurate result, one got a fairly reliable costing. One had an excellent summary of the costs which ought to be included, but one would find, in normal years, the cost of the lining materials and other things would vary a little. So long as one watched the coke market and pig-iron market, one could establish a figure of so much per cwt.—6s. 6d., 7s. or 8s.—and one could modify that figure subject to a substantial alteration in the price of raw materials.

Internal and External Orders.

Mr. E. Longden asked what difference should be made in placing on-costs for quotations for outside firms as against the same article made for one's own works. That was a very common thing in some factories, that the former should not bear the same on-costs as castings for their own product. Had Mr. Wintle considered the total amount of metallic loss in the sand in melting, in fettling, and in carrying about the foundry? He stated something about 6 per cent. in melting, but had he considered the loss in handling?

A Liaison Officer Desirable.

Mr. Goodwin said they would realise, from the Paper, that Mr. Wintle was able to detail a concise and understandable mass of figures from which the foundry manager could detail out his report, backed by the job costs that had already been mentioned. In the old days they had a sort of general summary, but when it was all done it was merely a mass of figures. Nowadays they had it broken into sections. On the right-hand side one had the complete costs. On the other side, the details were summarised and totalled, which enabled one to realise where the extra cost had taken place from the right-hand total figures. There should be some liaison officer between the costing department and the works department. It was difficult for the costing clerk, the junior or the accountant to realise what he was costing. One must create a connection between the office staff and the man in charge of the other department, or his foreman. He greatly welcomed that in the works at Sheepbridge, because, then, the man was not merely sitting in the office working at masses of figures, but he could realise what was happening down at the foundry. It gave one qualms to realise that a job which was expected to pay had not done so, but the error could be found out from careful costings. One item which was sometimes overlooked in the foundry and in the costing department related to a job which in going through might have occupied floor space considerably longer than the average job on which the average on-costs had been taken from the shop. A liaison officer would obviate that error creeping into the costs. An intricate cored casting, especially a dry-sand casting, might take a fortnight or even two months to complete. The total weight of that casting would be so much, and on to it, for wages, should be carried certain on-costs. But that was not going far enough, when one realised the enormous time that it had occupied a number of square yards in the fourdry and prevented further production. That was a little item which was not always looked at as carefully as it might be.

Loading the Metal Costs.

Mr. Lake congratulated Mr. Wintle on an excellent Paper. His Paper excelled over others because the author not only showed a fundamental knowledge of costing but of costings as applied to foundry work. He evidently had had enough experience in the foundry itself to be able to apply his principles of accountancy in a very successful manner. In his opinion, there was a very great difficulty in accurately proportioning the costs between the light intricate castings which took much moulders' and coremakers' time, with perhaps very little metal, and other jobs in which the main expense was the metal. That difficulty was best met by apportioning as large a proportion of the overheads as possible to the metal itself. He had found, by experience, that one obtained much better results in that way than by letting a large proportion of the overheads be apportioned to the direct labour. One piled as much on the metal as one could, so as to relieve the overheads on the moulders' and coremakers' wages. In that way, one ultimately got a much more accurate result. They all knew that it was necessary to have the monthly or weekly costs of the department as a whole. But, with regard to job costs, it could only be said that it paid for itself when dealing with foundries in which there were a comparatively small number of jobs dealing with large numbers of the same kind of thing. He had had experience of operating two foundries at the same time. One was making large numbers and from few patterns; the other one was making small numbers from a very large number of patterns. In the first case, it amply repaid the extra cost of taking out separately the cost of each job, and in the second case, he had never found that the extra cost was justified. Therefore, it was essential to have a costing system which was suitable for the particular needs of a foundry, and it took some consideration to judge what was best to suit the individual foundry.

Mr. Moore (Loughborough) said that Mr. Wintle's remarks were most interesting and valuable—even more interesting than his Paper. Did the small extra cost of the costing system absorb itself? The small amount of cost entailed, if it increased the turn-over and reduced the on-costs by the use of more direct labour, must be justified from any point of view. The on-costs must be known, and they must be absorbed. The question was raised referring to whether one was running a foundry alone or an engineering department with a foundry as an essential side of it. It seemed to him that did not matter; it was all a matter of knowing what one was doing. He agreed as to the necessity of costing departments and costing accountants knowing their job by being constantly in touch with the departments they were dealing with.

Large Unremunerative Orders.

Mr. Faulkner asked Mr. Wintle to explain the fallacy of taking on large orders at unremunerative figures in order to lower the overhead costs chargeable to the individual job?

Mr. Harley (Coventry) said the Paper went to the root of their prosperity, or lack of prosperity. After all, they were in business to make money, Unless they knew on what jobs they were making money, and the jobs on which they were losing money, they did not know where they were. Mr. Wintle was not only an expert accountant, but he seemed to be an expert foundryman; he knew precisely and exactly the different operations going on in the foundry and their relative importance. In costing, where the cost of the metal was relatively high, as in the steel foundry, and where the proportion of gates and runners was perhaps also relatively high in regard to the weight of the casting, he thought the cost, so far as the cost of the molten metal was concerned, should be the cost plus its gates and runners. In other castings, where the weight of the casting was high and the weight of the runners was small, it did not matter so much, but in the steel foundry it happened more often the other way. The actual cost of the metal in that casting was very high in some sections, apart altogether from the moulding costs, and the return value of the scrap was comparatively small compared with the cost of producing the steel which went into the runners. Apart altogether from what was done in taking out individual costs, he agreed that it was essential, no matter what the foundry was doing, or how many different classes of castings that they were dealing with, that they should have at least a monthly manufacturing account. Every month one should have that danger signal to tell one which way things were going. From that manufacturing account, one could see whether one had made any money or not. It did not tell one where one had made money, or where one had lost it, but one saw the net result, and from that one could derive very valuable data from the following month.

AUTHOR'S REPLY.

Mr. Wintle, replying to Mr. Longden, said the loading of a different percentage of establishment charges to castings for works consumption, as against those for outside sales, was rather strange from the cost accountant's point of view.

Assuming both lots of castings had been made under the same condition of manufacture, one failed to see any difference in the cost. But presuming the loading was done, it must incline heavily towards the works castings in order to lighten the cost of customers' castings and to make the selling price of such castings an attractive proposition.

One could appreciate that this is possible if the proportion of castings for works consumption was a fairly steady percentage of the output, but how the balance was kept level if they are not, must certainly be a little dangerous. In any case, the questioner would appreciate the fact that the establishment charges were necessarily higher on the works than they need be by this method, and the peculiarly unsatisfactory position arose from what appeared to be mere juggling with figures. Such unreliable deductions resulted in the following:—(1) An untrue value of works castings for consumption; (2) an untrue cost of customers' castings; and (3) an untrue cost of the real overhead charges. The recognised way to charge works with castings for own consumption was to make the open market the judge. If the selling price was lower than cost price, there is a double loss to bear which might work out to the same approximate result as the overloading method.

But the most important feature was retained. One obtained the true relative costs, which at least should be striven for. One could juggle with selling prices if one liked, but never with costs.

What Melting Losses Comprise.

The loss of 6 per cent. shown in the summary cost was the melting loss only. Any other losses due to heads, runners, risers, etc., was shown between the cost of the metal in the cupola, and the residual value of the amount left behind after the casting was fettled. It was generally assumed thatthis weight of metal was all returned to the cupola in due course, but the loss measured in terms of percentage is roughly from ½ to 1 per cent.

Replying to Mr. Lake, Mr. Wintle said that the policy of loading as much as possible of the overhead costs on to the weight to relieve the direct labour " on cost " was a matter for very careful consideration. It could be clearly defined in the case of the cupola what proportions of expense should be borne (see summary cost). In the matter of those other charges enumerated under Item 7, they were really representative of services rendered on the basis of time a job was in the foundry, and should, strictly speaking, be expressed as a percentage on the whole of the direct labour in the foundry. Therefore one could not endorse such a policy without knowing the full circumstances. It would appear another case of jugglery.

Regarding the value of job costs as being overrated, one can quite conceive, where a foundry is making castings of such a nature as to produce no violent fluctuation in cost, then quite rightly the job cost should give way to "class costs." The total summary cost was not sufficient guidance to good management and salesmanship.

Large Orders at Unremunerative Prices.

As to proving the fallacy of taking in a lot of orders at unremunerative prices to bring down the cost of overhead charges, as cited by Mr. Faulkner, strictly speaking one did not bring down the cost of establishment charges in terms of money by taking on more work. Expressed as a percentage on direct-labour or as a cost per ton, this reduction was true. One must assume that there was a fair quantity of work coming in at normal prices, which was presumably "paying." Much depended on what proportion of the normal establishment charges was recovered by these orders, and whether in consequence it was advisable to take on more work at prices which did not pay.

The only justification for doing this would be when the normal trading tonnage was reached and therefore abnormal conditions brought about in the shop. Here we came face to face with elementary economic teaching that as the demand would be exceeding the supply there would be no need to take work at unremunerative prices.

In the case of a foundry where work at normal prices could be obtained, it certainly appeared a fallacy, because no good purpose was apparently served; the resulting loss probably equalling the loss of keeping the place idle altogether. But there were one or two factors which must be taken into account. If the business was competitive, by taking some proportion of orders at low prices, one kept the name of the company advertised and held together a nucleus of custom. It also provided employment and kept together the personnel of the establishment. Much, of course, depended on the resources of a company. One could not say with any definite conclusion that to take orders on at unremunerative prices was fallacious.

When occasion arose, every shop must work it out for themselves, with all the conditions known, before a decision was reached. The deflating of the market in consequence of a decision to take such orders, if expensive, was a very serious business, and tended to lower the tone all round, which might have lasting effects.

In this connection the author quoted from an article by Mr. F. T. Clapham, who stated: "There is another curious instance of the unrealised value of establishment charges, which I should like to bring before you. I once obtained a foreign order for £30,000 worth of work, amongst which was 150 tons of C.I. special pipes. These specials were included in our estimate at £11 per ton. The foundry was badly equipped in one or two notable things, and, in consequence, was short of work. One of my directors sent out an inquiry for those specials and obtained a quotation for them at £10 10s. per ton. He said to me: 'I think it advisable to buy these out. In any case we stand to get a clear profit of £75, because I can buy the whole lot at 10s. per ton cheaper than our estimate.' 'Exactly,' I replied, 'but while you are getting £75 clear profit, you are paying away your own establishment charges.' 'How do you mean?' 'Just this. Our moulders can make these pipes at £2 per ton. The establishment charges, including cupola cost, are 30s. per ton. On 150 tons this works out at £225; deduct the £75 profit you say you can make, there remains a net loss of £150 charges.' I need hardly add that we made those pipes in the foundry, and although they cost the £11 a ton of the estimate, we actually earned £225 of charges, which were a great help to the inevitable running costs of the shop."

Vote of Thanks.

The President thanked Mr. Wintle, on behalf of the Convention, very much for his Paper and his introductory and other remarks.

Middlesbrough Branch.

PRACTICAL MOULDING SAND CONTROL.

By N. D. Ridsdale (Member.)

The scope of this Paper will be to deal mainly with "green" sands such as are used for iron and brass founding, and to indicate the nature and value of small scale tests both within and without the laboratory for assisting the practical moulder to use his sands to the best advantage. Prominence will be given to tests of a sufficiently simple kind which can be carried on by the moulder or foreman in the foundry, without necessarily requiring the services of a specially trained technical man.

The Properties of Green Sand.

In order to control moulding sands, it must first be realised what sort of tests will yield any information of real importance. Before dealing with this it is as well to review the essential nature of "green" moulding sand. It is a mixture of grains of sand stuck or bonded together with perhaps 10 or 20 per cent. of clay. The sand consists of fairly pure silica in the form of quartz. The clay is a more or less pure silicate of alumina. Curiously enough pure kaolin or china clay is not as good a bond as are many impure clays. The clay contains both free and combined water; the free water, termed "moisture." may be removed by drying at the temperature of boiling water (100 deg. C.), whereas the combined water is only removed progressively as the temperature rises from 100 to about 600 or 700 deg. C. (dull red). Once this water is completely driven off by heat the plasticity of the clay is destroyed and cannot for practical purposes be restored. The removal of *free* water ("moisture") will not affect the life of a clay.

The sand grains vary in size from, say, 2 mm. diameter down to 1/10th mm. dia.; whereas the clay particles may be taken at less than 1/100th mm. dia. Most sands contain material between 1/10th mm. and 1/100th mm. in dia. which, in a virgin sand, may be regarded as fine rubbings from the sand grains. This material is known as "silt." In a floor sand, silt is derived partly from the "dead" burnt clay and unburnt coal dust. Silt is objectionable, because it has no binding properties like clay, but on the other hand it tends to diminish the stickiness of the clay and fill up the interstices of the moulding sand, also increase the amount of water to be added. Iron oxide is frequently associated with clay and up to 5 or 6 per cent. is regarded as advantageous, inasmuch as it has valuable binding properties which are not so readily destroyed by heat as they are in pure clay. These so-called "ferruginous" or red sands are consequently more durable. The more rounded in shape the sand grains are and the more regular in size, the more "open" is the sand likely to be.

The refractoriness of a moulding sand—that is to say, its resistance to fusion at high temperatures—is an important property, especially in the case of steel moulding sands, where the temperature of casting is considerably higher than that of cast iron.

The fusibility, again, is not dependent on the sand grains so much as on the quality of the bond, which, at best, melts at a lower temperature than the sand grains. Impurities such as lime, magnesia, soda and potash derived from the presence of minerals known as felspar, all tend to make the bond more fusible.

Desirable Tests to Perform.

It will be seen that the suitability of a moulding sand may often be best arrived at by studying separately the nature of the sand grains, the silt and the clay. The following tests give useful information:—(*a*) Fineness; involving sieving, elutriation or sedimentation tests to determine the proportion of sand grains, silt and clay; (*b*) mineral and "rational" analysis giving the amount of sand, felspars (minerals just referred to tending to increase the fusibility), and clay; (*c*) microscopic examination; (*d*) chemical analysis; (*e*) permeability (openness or venting qualities); (*f*) binding properties, or strength; (*g*) refractoriness; and (*h*) durability or "life."

Sampling.

Before dealing with these tests in detail it will not be out of place briefly to mention the question of sampling. Unless a reasonably representative sample of the bulk is obtained, the whole series of tests may be misleading and of little value. Heaps of sand may be quite uniform to the eye when in fact the distribution of the clayey matter and the size of the sand grains may vary considerably, and one shovelful from the surface of a heap is not sufficient to represent the bulk; a number of shovelfuls should be taken from different points both on the surface and deep down in the heap. A sample so obtained should be thoroughly mixed and a small sample drawn from it after quartering down several times. A long 2-in. tube, cut in half lengthwise to make a sort of magnified cheese tester, is a useful implement for sticking into sand heaps to draw samples. In sampling quarries, samples should be taken from the entire cross-section (vertically) of the surface of each layer at a number of different points along the face.

Fineness.

Sieving tests may be made with a series of standard sized sieves such as those recommended by the Institute of Mining and Metallurgy or the American Foundrymen's Association, but as these have to be done on the *dried* moulding sands the author does not regard them as of much value except for determining the larger grains—say, down to 0.5 mm.—because the dried particles unavoidably cake together to some extent and must give somewhat misleading results. By suspending moulding sands in water the particles lose their cohesion for one another, and may more readily be separated.

The process of elutriation is one which involves considerable time and patience and is not suited to works conditions. Particulars of this method may be found in the "Memoir of British Resources of Refractory Sands," Part I, by Prof. P. G. H. Boswell, O.B.E. (1918).

Sedimentation tests of a simpler and quicker kind have been brought to notice of foundrymen in a previous session by Mr. J. E. Fletcher.*

Mineral and Rational Analysis.

Mineral analysis consists of separating the various minerals from the quartz grains; immersing the dried sand or silt washed free from clayey matter in heavy liquids of known density; for instance, in a solution of bromoform. Quartz and felspars, which are of a density below 2.76, will float while other heavier minerals will sink and may be separated and identified under the microscope. An outline of the method of mineral analysis of sands will be found in the "Memoir of Refractory Sands" already referred to.

With regard to "rational" analysis of moulding sands, a method recommended by Signor G. Guilo Sirovich (Rome) in the "Bulletin de l'Association Technique de Fonderie," September, 1927, in his Paper on the "Tests and Properties of Foundry Sands," is worth studying by chemists. By a simple treatment with acids and caustic soda sands may be resolved into quartz, clay, and felspars, and the amount of each determined. Erith sand is by this method shown as containing 76.38 quartz, 13.50 clay, and 10.11 per cent. felspar.

Microscopic Examination.

This is useful in connection with mineral analysis; it is also useful in revealing the shape and surface appearance of the sand grains and the extent to which the grains are coated with the claybond. It also furnishes other information, but space will not permit dealing with this method of examination in detail.

Chemical Analysis.

Personal opinion about complete chemical analysis is that the information it supplies is not often worth the time it takes to make it. A few short tests, for instance, for iron and carbonate of lime, are useful. Most of the information it gives can be gleaned by other and simpler means.

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* *Foundry Trade Journal*, Nov. 4, 1926, pp. 391-2.

If a chemical analysis is made it should be made on the sand grains, silt, and clay, separately, as this throws much more light on the nature of the components of the moulding sands. Take, for example, the following analysis of Compton red moulding sand, Table I, taken from the "Memoir on Refractory Sands," Part II, pp. 161-2, wherein

TABLE I.—*Bunter Moulding-sands.*

COMPTON SAND.

Chemical Analyses of Grade.

Analysis of sand as a whole. (dried).		MS. >0.25 and <0.5 mm.	FS. >0.1 and <0.25	cs. >0.05 and <0.1	fs. >0.01 and <0.05	c. <0.01 mm.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
86.90	SiO_2	94.37	89.10	85.31	69.05	58.17
6.43	Al_2O_3	2.82	5.32	6.95	14.15	19.58
0.98	Fe_2O_3	0.46	0.88	1.23	2.70	5.57
0.25	FeO			0.22	0.53	0.55
0.42	MgO	0.17	0.28	0.37	1.05	1.78
0.26	CaO	0.16	0.24	0.41	1.27	1.34
0.36	Na_2O	0.12	0.15	0.49	0.56	0.38
3.26	K_2O	1.57	3.13	3.31	5.45	5.37
0.35	TiO_2	0.06	0.21	0.43	0.97	0.73
1.00	Loss on ign.	0.48	0.71	1.43	4.28	6.34
100.18	Totals	100.21	100.02	100.15	100.01	99.71

MS. = Medium sand; cs. = coarse silt; c. = clay; FS. = Fine sand; fs. = fine silt.

the analysis of the bulk does not tell very much about the sand, but the analyses of the separated grades show, for instance, that the sand grains (MS. and FS.) evidently contain an appreciable proportion of felspars, since the alumina and alkalies are both fairly high. The clay is quite ferruginous, having about 6 per cent. iron oxides; moreover, it cannot be very refractory since it contains over 5½ per cent. of alkalies (soda and potash). The value of an ordinary complete analysis of moulding sand is greatly enhanced if the approximate mineral composition in terms of quartz, felspars, clay, etc., be calculated from it.

An example given by Prof. Boswell is shown in Table II.

TABLE II.—*Showing Mineralogical Composition.*

	Per cent.
Silica	75.91
Alumina	9.44
Ferric oxide	3.26
Ferrous oxide	1.86
Magnesia	0.64
Lime	1.12
Soda	1.42
Potash	2.96
Titanic oxide	0.64
Loss on ignition	2.91
Total	100.16

Anal. W. J. Rees.

Mineral Composition calculated from the above :—

		Per cent.
Quartz		51.63
Lime felspar	5.57	
Soda felspar	12.05	
Potash felspar	17.53	
		35.15
Clay substance		4.74
Hydrated iron oxide		6.13
Other constituents		2.51
Total		100.16

If the "rational" method of analysis already referred to is satisfactory it is a much quicker means of arriving at the mineral composition. It does not, however, show how much of the quartz exists as silt nor how much hydrated iron oxides are present. The rapid determination of moisture in moulding sands is a matter of great significance, particularly in connection with preparing the sand heap.

It is important to remember that the sand should carry the least possible moisture which will give it the maximum strength; any excess beyond this may weaken the bond and is simply adding to the amount of steam which must be driven from the surface of the mould when the iron is cast. Further, it may cause blowholes and surface defects on the castings.

Amongst the rapid methods for the determination of moisture may be mentioned the moisture apparatus of the Dietert type.* It is illustrated in Fig. 1. The tube is closed at the top by a plug containing an electrical heating wire surrounding a compressed-air pipe; the bottom of the tube contains a small sieve (*d*) which contains the sample to be tested. The compressed air is heated to 200 deg. C., at which temperature the sand is dried in a few minutes. The same investigator uses a method depending on the compactness of the sand being related to the moisture content. This method will be referred to later on in connection with the permeability tests.

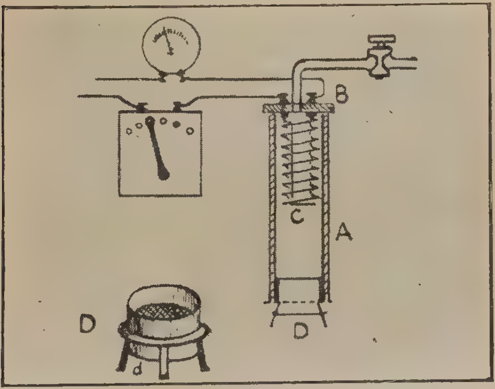

FIG. 1.—DIETERT MOISTURE TESTER.

Fig. 2 shows the McIlvaine moisture meter. It consists of a long tube which is filled with the sand to be tested by plunging it into the heap. At the top of the tube is a milli-voltmeter, and when a small electric current from a dry battery is passed through the column of sand, the reading on the meter indicates the amount of moisture present. The higher the moisture the lower is the electrical resistance, and *vice versa*. The meter is standardised by noting the reading at a predetermined moisture content of the sand. The meter is, it is thought, used extensively in America, and in one or two foundries in this country. It should be invaluable to the foreman in checking the evenness of the distribution of moisture from day to day and at different points of the sand heap.

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* Proceedings, I.B.F. ,Vol. xix, pp. 82-83.

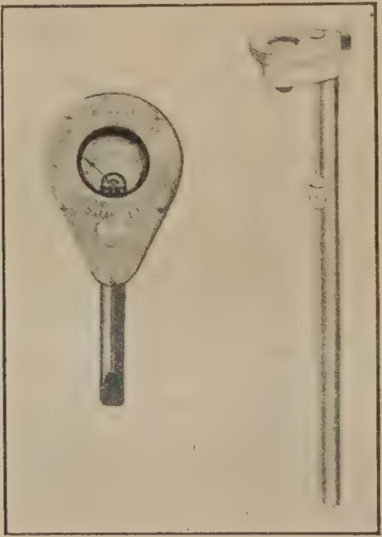

FIG. 2.—McILVAINE MOISTURE METER.

Permeability.

The American Foundrymen's Association, after several years' investigation, has evolved a test for permeability which is probably one of the best which is available to-day. It has the disadvantage of only measuring the permeability at atmospheric temperatures instead of under the conditions of casting, but it is worthy of attention in spite of its limitations. The permeability is measured by forcing air through a column of sand 2 in. long and 2 in. in dia. formed by ramming the sand in a standard manner by means of the rammer shown in Fig. 3. It consists of a steel rod supported by two guides; a steel disc is attached to the lower end of the rod and has a sliding fit in the sand container (*a*). A cast-iron rammer head, W, weighing 14 lbs., slides on the rod between two stops which allow only a 2-in. movement on the rammer head. A suitable quantity of sand must be taken (by trial) to yield a column of sand 2 in. long with a tolerance of 0.08 in. The rammer head is raised to the top stop and allowed to fall three times whilst the steel disc at the bottom end of the guide rests on the sand in the cylinder. After the sand has been rammed an indication of the moisture content may be obtained by means of the pointer, N, being swung into position. A given weight of sand will be compressed further into the cylinder as the moisture content is increased, and the

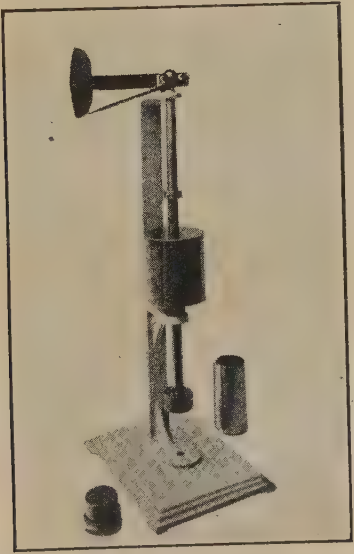

Fig. 3.—Rammer used for Testing Sands.

pointer simply indicates how far the plunger has descended into the cylinder. The scale must be calibrated by compressing each type of sand with pre-determined amounts of moisture in increments of, say, 2 per cent. This device is the one already referred to under moisture determinations and has been put forward by Mr. Dietert. After reading the moisture the pointer is swung out of position, the guide is lifted and the cylinder is connected with the permeability apparatus shown in Fig. 4. It consists of a bottle, B, having a capacity of 3 or 4 litres and fitted with a large cork at the top. On the side are two marks, the lower one about 3 in. from the bottom and the higher at such a point that the volume of water between the two marks is exactly 2 litres. Tube C extends through the cork, within 1 in. of the bottle. On the outside it is connected with a tap. The tube should be 2 in. in dia. The next tube, D, starts just within the top of the bottle, the other end passing through the rubber stopper, E, to which is attached the gunmetal cylinder, H, which contains the 2 per cent. column of sand to be tested. Through stopper E also passes another tube, F, which is connected with U, tube G, about 2 ft. long and behind which is a scale

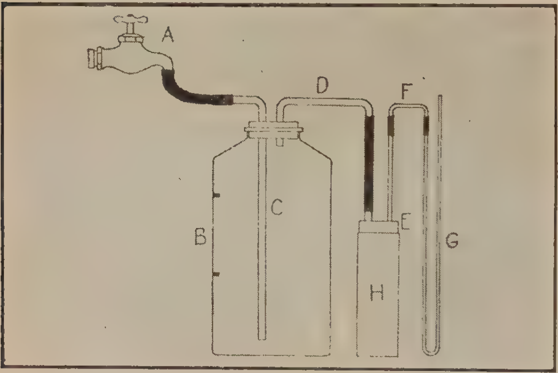

Fig. 4.—Permeability Apparatus.

divided into inches. To use the apparatus, after connecting the sand cylinder, H, the tap is opened until water flows into the jar steadily at such a rate that the water in the U tube stands from 1 in. to a foot higher in one leg than in the other. Then, as the water rises in the jar the time is taken for the level to rise from the one mark on the bottle to the other, and the difference in level of the water in the two legs of the manometer is measured whilst the water in the bottle, B, is rising between the two marks. The permeability is calculated by multiplying the difference in water level in inches on the manometer by the time (in seconds) taken for the water to rise between the two marks of the jar and dividing this into 11,700. This gives the permeability of the sand in centimetre-gram-minute units. This means the number of cubic centimetres of air which would pass through 1 cub. cm. of sand

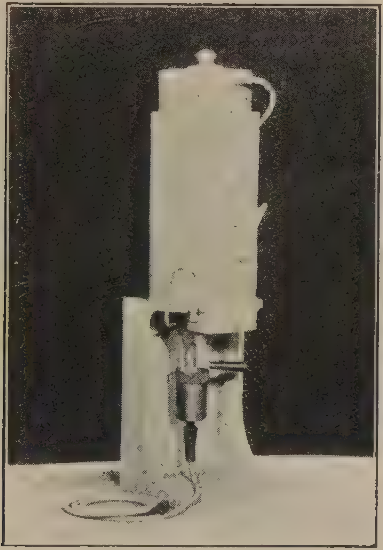

Fig. 5.—Permeability Apparatus for Works Use.

in 1 min. if the pressure difference is 1 grm. per sq. cm.*

This piece of apparatus, whilst giving satisfactory results, is somewhat fragile in the hands of those unaccustomed to glass apparatus. An improved portable apparatus based on exactly the same principle has been evolved by the American Foundrymen's Association. This is shown in Fig. 5. It contains no glass parts, and may be used to determine the permeability of sand moulds in position as well as sand from heaps, etc.

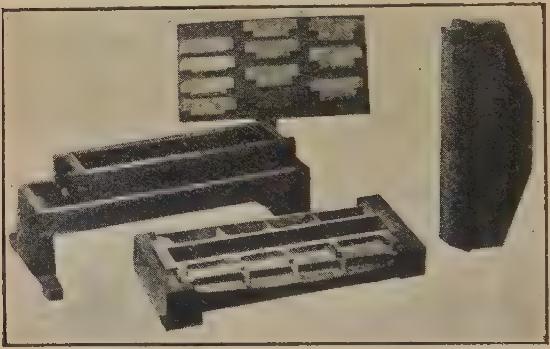

Fig. 6.—Mould for Preparing Test Piece.

The permeability of dry sands could no doubt be determined in either of these pieces of apparatus by slightly modifying an ingenious method devised by Mr. O. Smalley.†

Binding Properties or Strength.

Here again the American Foundrymen's Association has gone into the question very thoroughly and evolved a standard method of making valuable comparative tests. The standard test piece is prepared in a special moulding box, shown in Fig. 6. The sand in the box is levelled off by using a series of strikes, as it is gradually filled with sand, and then a trussed rammer, shown on the right, is placed in position over the mould, which is subjected to a definite impact by means of a weight of 20 lbs. falling three times from a height of 16 ins. The test piece is then stripped and placed on the pulling device shown in Fig. 7. It will be seen that the test piece is laid on a piece of thin oiled paper at the edge of a flat table. The motor pulling device draws the paper forward at a definite speed and causes the end of the test piece to overhang. When the overhanging section of the bar breaks off by its own weight, the motor is stopped. The portion breaking off is caught in a convenient receptacle and weighed. It is clear that the stronger the sand the greater will be the portion projecting over the edge before it breaks off. This method takes an appreciable time to carry out, and involves the use of special and somewhat costly equipment. A much simpler and reasonably satisfactory method is to subject the sand test-piece used for the permeability determination to a gradually increasing compression until the test piece is shattered. Mr. Dietert has devised a compressing machine, illustrated in Fig. 8. The pressure is applied by means of oil, which is compressed by turning the handle on the

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* Proceedings, American Foundrymen's Association, Vol. xxxii, Part II, p, 120.

† Proceedings, I.B.F., Vol. xvi, p. 327.

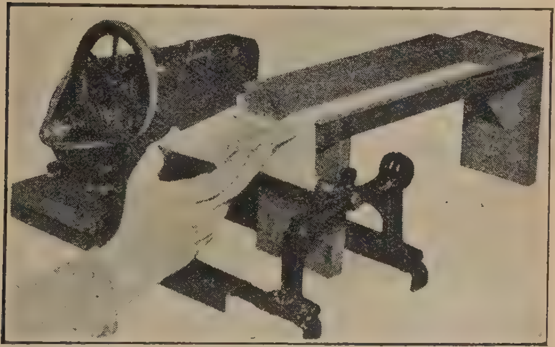

FIG. 7.—PULLING DEVICE FOR STRENGTH TESTS.

right. As soon as the test piece shows signs of collapsing the pressure is stopped and its amount read off on the dial on the left; for the strength of *dried* sands the dial on the right is used. The saw shown in Fig. 8 is used for partly sawing through test pieces of oil-sand cores before subjecting them to compression. Fig. 9 shows a complete equipment for testing green, dry and core sands.

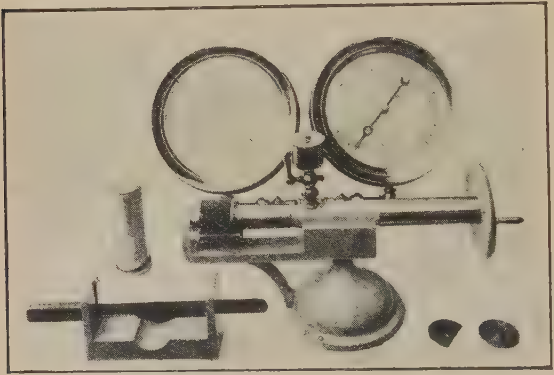

FIG. 8.—COMPRESSION TESTING MACHINE.

Experiments on Locally Used Sands.

The author has made a simple beam compressor which applies pressure to the test piece whilst in a vertical position by means of a sliding weight on the beam. Pressure can be gradually applied until the test piece collapses. A series of tests on sands used locally have been made at different moisture contents in order to determine the most suitable percentage of moisture to give both the maximum permeability and compressive strength.

Table III shows tests made on moulding sand from Heck, Mansfield and Northallerton; also on some black floor sand in a pipe foundry. It will be seen that Heck sand has a maximum strength at 4.3 per cent. moisture; increasing moisture causes the strength to diminish steadily. A noteworthy feature of this sand is the low moisture (viz., only 4.3 per cent.) required to give maximum strength. The permeability increases with the moisture until 6 per cent. of water is present, after which it again diminishes. The best moisture content for working this sand is evidently between 4 and 6 per cent., though the sand as received

TABLE III.—*Tests of Moulding Sands.*

Name of sand.	Per cent. moisture.	Compression strength (lbs. per 2″ dia. Cyl.)	Permeability c.c.—grms. mins.
Heck	3.3	11.7	63
,, ..	4.3	15.4 (max.)	100
,, ..	6.0	12.8	121 (max.)
,, ..	7.3	11.4	99
,, ..	8.8 (as rec'd.)	10.1	91
,, ..	10.0	10.2	93
Mansfield ..	3.1	5.0	19
,, ..	4.0	12.8	27
,, ..	6.0	15.4 (max.)	28
,, ..	9.7 (as rec'd.)	10.6	31
,, ..	11.0	11.5	33 (max.)
Northallerton	6.4	12.6	46
,,	8.2	11.9	50
25 per cent. Northallert'n 75 per cent. Floor	8.0 (approx.)	8.9	61
Black Floor ..	3.1	Too dry to bind.	—
,, ,, ..	4.4	5.7	50
,, ,, ..	5.5 (as rec'd.)	5.7	59
,, ,, ..	6.8	6.0	64
,, ,, ..	7.3	6.4 (max.)	76 (max.)
,, ,, ..	9.0	5.4	76

contains 8.8 per cent. moisture, which is more than is desirable. Mansfield sand is about as strong as Heck sand, but it will be seen that the permeability at its maximum strength is only about one quarter that of Heck sand.

Northallerton sand does not appear to be quite as strong as the other two, but it is appreciably more open than Mansfield, though it only has about half the permeability of Heck. When three parts of floor sand were mixed with one part of Northallerton, the strength was increased from about 6.4 to 8.9 lbs., but the permeability was somewhat diminished. When a virgin sand is used to rejuvenate floor sand, one should be selected which will increase the permeability as well as the strength. Probably the reason for the reduced permeability in this case was due to the fact that the black floor sand consists mainly of Heck sand, which is much more open than Northallerton.

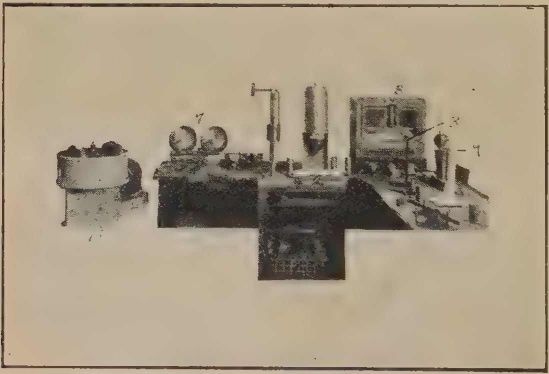

Fig. 9.—Complete Equipment.

Table IV shows tests made on Erith medium moulding sand, and Sinderby sand, which is a red open sand carrying very little bond. It is remarkable that Erith sand has a strength of 13 lbs., with only 1 per cent. moisture. By the way, it should be remembered that the moisture referred to in these tests is in every case that which is driven off up to about 100 deg. C., and does not include the combined water which is only driven off at higher temperatures. The maximum strength of the Erith sand was obtained when the moisture rose to 11.8 per cent., whereas the maximum permeability occurred with the moisture at 7.8 per cent.

TABLE IV.

Name of sand.	Per cent. moisture.	Compression strength (lbs. per 2″ dia. Cyl.)	Permeability c.c.—grms. —mins.
Erith mild loam	1.6	13.0	24
,, ,,	3.6	13.0	29
,, ,,	5.2	13.0	30
,, ,,	7.8	17.0	32 (max.)
,, ,,	9.9	17.2	25
,, ,,	11.8	20.4 (max.)	26
Sinderby ..	2.6	Too dry to bind.	—
,, ..	4.2	3.8	93
,, ..	6.2	4.8	95
,, ..	9.0	4.0	109
Mixtures. Erith. Sinderby Per cent. Per cent.			
0 100	9.0	4.0	109
25 75	8.9	13.8	60
50 50	8.9	14.9	38
75 25	8.9	16.0	36
100 0	8.8	17.1	29

The mixture of Erith and Sinderby sands gave some interesting information. It will be seen that when 25 per cent. Erith was added to 75 per cent. Sinderby the compressive strength rose from 4 to 13.8 lbs., whilst the permeability diminished from 109 to 60 cub. cm.-grms.-mins. Increasing the Erith up to 50 per cent. only slightly raised the strength of the sand, but considerably reduced the permeability, viz., from 60 to 38 cub. cm.-grms.-mins. A further increase of Erith up to 75 per cent. again slightly increased the strength, and only slightly further diminished the permeability. This table shows that if it is desired to open up Erith with Sinderby sand it is practically no use adding less than 50 per cent. of Sinderby, and to make any appreciable increase in permeability something like 75 per cent. Sinderby is needed. This may be a revelation to some who may have thought that an addition of, say, 25 per cent. Sinderby would appreciably improve the venting properties of Erith sand.

Refractoriness or Temperature of Fusibility.

A direct method of measuring the refractoriness of a sand is to mould it into small cones the same size as seger cones, and after having baked these dry, subject them to a gradually increasing temperature along with several seger cones of known melting points ranging from, say, 1,250 to 1,600 deg. C. When the sand cone softens and bends, the source of heat is cut off and a note made of the highest seger cone which has also softened in the same way. The heating may be conducted in a small vertical electric furnace lined with suitable resistance material. A furnace of this kind is used by research workers in the pottery districts. A simpler type of furnace may be constructed by boring a 2 in. diameter × 2 in. deep hole in a magnesite brick. The brick should be held together by means of a steel casing and placed on a disc, which can slowly be revolved. Pointing down vertically on to the hole is an oxy-acetylene burner held with a clamp, which can be raised and lowered at will by turning a handle with a long screwed rod with a fairly coarse pitched thread. In this way the oxy-acetylene jet may be gradually lowered into the hole, at the bottom of which are the seger cones and the sand cones, mounted vertically on a disc of asbestos sheet held in position with alundum cement. By slowly revolving the furnace whilst the oxy-acetylene flame descends into it the temperature is sufficiently uniform to enable the refractoriness of the sand cone to be compared with that of the seger cones of known melting point.

The value of a test of this sort is that it may be conducted in a foundry where there is no laboratory, once the man in charge has been instructed and had a little experience with the test. The method of measuring refractoriness described by Mr. D. W. Trainer, Junr.,* may prove to be more useful, but it needs to be conducted in a properly equipped laboratory. The tests in his method were carried out in a muffle furnace capable of attaining a temperature of 1,500 deg. C. Mr. Trainer unfortunately, however, does not give particulars of the source of heat for this furnace.

Durability.

A method of comparing the durability or life of moulding sands was given by Mr. C. M. Nevin at the October, 1925, meeting of the A.F.A , but space will not permit dealing with this subject on this occasion.

The lists of tests recommended may appear formidable. However, it will be seen that the tests which are required for new deliveries of sands used regularly, and for floor and facing sand control are, fortunately for the foundryman, those which may be carried out quickly in the foundry, with a little practice, without expert control, viz., moisture, permeability and bonding strength. Durability and fusibility tests may also be made by him, but take longer. These, however, should only be occasionally needed.

Finally, it must be remembered that the properties of moulding sand may be entirely altered by the amount and quality of coal dust used in the facing sand mixture and the nature of the blacking used. The author here takes the opportunity of thanking the firms who have kindly provided him with samples of sand.

It seems apropos to conclude by quoting Prof. Boswell's words at the end of his book on "British and American Foundry Practice," pp. 93 and 94:—

"Although the subject of moulding sands appears to be a commonplace and relatively unimportant matter, there is a great issue at stake. The saving which can be effected in time, labour and money is literally enormous. . . .

"The products of a foundry now play a large and important part in the life of the community.

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* Trans-American Foundrymen's Association, Vol. xxxiv, p. 327

The foundryman is a highly skilled, conscientious and thorough worker. Good work and sound citizenship will be maintained in the future only by the better education of the workers.

"If, as seems to be the case at the present time, we are ahead of many other nations in both research and works practice in connection with foundry problems, it will only be by continued attention to such questions that our supremacy will be maintained."

The Paper was followed by a short demonstration of permeability and bond-strength tests in machines, the design of which was based on information supplied by the American Foundrymen's Association.

DISCUSSION.

Mr. Ritchie said it would be very interesting to know the effect on tests for permeability and compressive strength if a different number of rammings were given, say more or less than the usual three.

Mr. N. D. Ridsdale, in reply, said that in order to get comparative data, it was necessary to stabilise factors or one would get too many variables. There was no reason why the ramming should not be varied, but this would involve a series of tests for permeability and strength at different moistures with each particular degree of compression.

A Member remarked that one important point which was not very fully dealt with was the influence of coal dust on the sand. Some investigators had given papers on moulding sand, but in each case they had dismissed the influence of coal dust in a sentence or two. Coal dust considerably modified the properties of the sand, and it seemed desirable to have a Paper entirely devoted to the subject of sand mixed with coal dust.

Mr. N. D. Ridsdale agreed that it would be very instructive and useful to know the modifying properties of coal dust, but insisted that it was a question which needed special study individually, and the subject with which he was dealing had such a wide scope that many such interesting points had to be left out. Reference to the point was made by Mr. Fletcher in connection with his Paper given before the Branch a year ago.

Mr. C. H. Ridsdale said that it must be remembered that there was a great variety in coal, and that to deal thoroughly with the question one would need definite standards of coal and definite standards of sand; as there are 12 keys on the piano from which can be obtained a number of variations, so in this case one would need to make thousands of experiments of mixtures of sand and coals and it would mean an enormous investigation.

Necessary Properties of Coal Dust and Blacking.

Mr. N. D. Ridsdale said that in one foundry he noticed coal dust mixed with facing sand to an amount far beyond the point at which it could become effective; much of the coal dust was, therefore, serving no useful purpose, but was only clogging the porosity of the sand. It is important to remember that the function of coal dust is that it should burn readily and form a sort of gas pad to protect the surface of the mould. The coal used, therefore, should be high in volatile matter and low in ash, which latter should not be readily fusible. On the other hand, the blacking or other surface coating of the mould should resist burning, and, therefore, be low in volatile matter, and any ash or mineral matter it contains should be very refractory, which latter point is often overlooked.

Mr. Chester remarked that it was difficult to know what was Erith sand. Twenty-five years ago there was only one sand which came from the Thames and known as Erith. The only Erith sand sent to this district was supplied to the Stockton foundries.

Mr. N. D. Ridsdale said that the sample of sand supplied to him as Erith sand did not come from Stockton.

Scottish Branch.

SOME DEVELOPMENTS IN ENGINEERING BRONZE FOUNDING.

By F. W. Rowe, B.Sc., M.I.M.M. (Associate Member).

Mr. Rowe said that though the developments and improvements which had taken place in engineering bronze-founding in recent years had not been so rapid as those which had taken place in the light alloy founding industry, nevertheless, the engineering bronze-founding industry had not stood still. The stress of competition during the last few years had made it imperative that more rapid and cheaper methods of production be adopted. The high cost of bronze castings had also resulted in the weight being cut to the very minimum, and the stresses which bronze castings were now subjected to were such that only first-quality material was able to withstand them.

One of the most important points in this branch of engineering was the method of melting the metals and alloys for casting. Good melting practice with the use of suitable raw materials was half the battle, and all the time and trouble expended on this part of the process was amply repaid both as regards costs and the quality of the work produced.

Probably 70 per cent. of the bronze melted in this country was melted in coke-fired pit furnaces. One of the main factors in the case of a crucible pit fire was the fuel consumption. Figures varied in this direction, but even the best figures for fuel consumption showed a very low thermal efficiency. He had taken figures in various foundries, and the best he had been able to get, working with Admiralty gunmetal or a similar alloy, was about 38 lbs.

of coke to 100 lbs. of metal. This represents 7 per cent. efficiency. Of course, these figures were very poor, but startling as they might seem, they were better than the figures obtained in steel melting in a crucible pit fire where the efficiency was about 4 per cent.

The next most important item was, of course, the cost of the crucibles themselves. Here again figures varied as to the average life of a crucible, but with small pots 50 heats on an average was a very good life. In the case of larger pots it was very seldom that they were able to maintain so high an average. The figure generally fell to about 35 or 40 heats.

It would be seen from Table I that the crucible cost per ton represented about 20 per cent. of the total melting cost, and that the fuel cost represented about 30 per cent. of that figure. Naturally, attention had been directed in recent years both to improving thermal efficiency and cutting out the cost of crucibles. Most of the furnaces recently installed were of the non-crucible type, and showed a high thermal efficiency compared with the old crucible furnaces.

TABLE I.—*Cost of Operating a Crucible Pit Fire Furnace.*

Alloy, 12 per cent. Tin Bronze.

Total operating time	9½ hrs.
Charge weight	160 lbs.
Melting time	1½ hrs.
Casting temperature	1,200-1,250 deg. C.
Weight melted per day ...	960 lbs. (6 heats).
Fuel cost per ton (38 per cent.)	17s. 6d.
Labour per ton...	18s. 6d.
Crucible cost per ton	10s. 6d.
Repairs per ton...	2s. 0d.
Depreciation and interest ...	1s. 3d.
Total cost	49s. 9d. per ton.

The next most popular method of melting was to use the tilting type of crucible furnace, such as the M.R.V. or Morgan furnace. In practice this type did not show a great economy over the ordinary pit fire, the great advantage of the tilting crucible furnace being that it could deal with a greater amount of metal at the one time. With the tilting type 600 to 800 lbs. was quite a common capacity. In discussing all these cost figures he should point out that it was usually possible, by "sitting over" a furnace and keeping it in really first-class condition, to reduce these costs. But the figures he had given them were those obtained over a six months' period, and he did not think they could be very much improved upon.

Reverberatory Furnaces Reduce Melting Costs.

At Huddersfield they had installed a battery of tilting reverberatory furnaces for the major portion of their production. The battery for the centrifugal bronze foundry consisted of three half-ton units and a one-ton unit. They found that with this type they very materially reduced their melting costs. They are illustrated in Fig. 1.

Table II showed a cost sheet taken out for a six months' period with a half-ton reverberatory furnace. The fuel cost per ton had been cut down to 12s. against 17s. 6d. in the case of the pit-fire type. With the reverberatory furnace, of course, more money had to be spent on the lining, but the net result, after allowing for that extra expenditure, was that they had been able to reduce their melting cost from about 50s. to about 29s. per ton. The half-ton furnaces were giving about five heats per day in a 9½ hours' day, but that was not the maximum capacity of the furnace. If they were able to take the whole of the

TABLE II.—*Cost of Operating a ½-ton Reverberatory Furnace.*

Alloy, 12 per cent. Tin Bronze.

Total operating time	9½ hrs.
Charge weight	1,120 lbs.
Melting time	1 hr. 15 min.
Casting temperature	1,225-1,275 deg. C.
Weight melted per day ...	5,600 lbs. (5 heats).
Fuel cost per ton	12s. 0d.
Labour per ton...	11s. 0d.
Current and repairs per ton...	3s. 0d.
Depreciation and interest per ton	3s. 0d.
Total cost	29s. 0d. per ton.

metal immediately it was ready for pouring they could get another heat. The first heat with the half-ton furnace took from $1\frac{1}{2}$ to 2 hours. After that they could get another heat about every 75 minutes, depending on the size of the metal or the scrap. The one-ton furnace was chiefly used for remelting the turnings and borings from the machine shop into ingots.

The main trouble with that type of furnace had been to find satisfactory lining materials, and methods of making the lining stand up to wear and tear, particularly in the fire-box. The furnace developed a very high temperature in the fire-box—about 1,650 to 1,700 deg. C.—and they had considerable difficulty in finding a refractory that would stand up to that temperature. They now lined the fire-box with sillimanite bricks, arranging the direction of the brickwork to the best advantage. One of the main factors with this furnace was to keep the lining really clean. If the furnace was dirty, with slag on the sides and the hearth, poor results were obtained. They made a special effort to keep the lining in such a condition that they could see every brick in the furnace at the end of the day. A certain amount of extra coke was used in that way, but that was taken into account in the figures given for fuel cost per ton. They spent 20 to 30 mins. every night getting the furnace heated up for this purpose, and in addition to that, every two or three weeks they brought the furnace up to the requisite heat, removed the tapping plate, and scraped it thoroughly to expose every brick in the furnace.

One of the most serious competitors in the near future would be the electric furnace. He was afraid that in this country they were apt to dismiss the question of electric heating too lightly. When one mentioned electric heating and pointed to the wonderful strides made in this direction in the United States, the most frequent remark made was that it was too dear in this country, and that only the low price of power in America enabled electric furnaces to be used. He thought, however, that these objections were not strictly accurate. The average price paid for power for industrial heating in the States was not much lower, if any lower, than the price which would be charged by any progressive electrical undertaking in this country. They should remember that in America they had vast supplies of oil fuel, which could be bought at a much cheaper price than they could get it in this country. In Britain to-day oil fuel cost about 90s. per ton; in the States it cost about 50s. per ton. It would seem reasonable to suppose that oil fuel would be used more than electric heat if it was as good. Pretty nearly any electrical undertaking in this country would charge considerably less than a penny per unit for current for industrial heat, yet in America many people were paying more than that.

The main item in the installation of an electric bronze melting plant was the high capital expenditure involved, and, of course, the subsequent high overhead charge in depreciation. In the United States most of the foundries were equipped with Detroit rocking-arc electric furnaces, shown in Fig. 2.

The chief disadvantage of this type was that it worked with single phase. It was very extensively used in the States, where between 500 and 600 of them were in operation at the present time. Table IV showed the figures for the working of a larger type of Detroit furnace (750 lbs.).

TABLE III.—*Cost of Operating Induced Draught Crucible Furnaces.*

Alloy, 12 per cent. Tin Bronze.

Total operating time	9 hrs.
Charge weight	400 lbs.
Melting time	1¾ hrs.
Casting temperature	1,200-1,250 deg. C.
Weight melted per day ...	2,000 lbs. (5 heats).
Fuel cost per ton (35 per cent.)	16s. 0d.
Labour per ton...	18s. 0d.
Crucible cost per ton	12s. 0d.
Current and repairs per ton...	2s. 6d.
Depreciation and interest per ton	2s. 0d.
Total cost	50s. 6d. per ton.

The figures given were obtained from a large works in the States. If it were not for the heavy depreciation charges, it would certainly form a very economical proposition. Eight heats of 750 lbs. each at a penny per unit—rather more than was being paid—was 24s. per ton, as against 17s. 6d. for a crucible pit-fire furnace. These figures were taken over a long period. The labour required for an electric furnace was very little, one man being able to work a 750-lb. furnace without any trouble. All he had to do was to put the metal in, switch on the current, and keep it properly adjusted. The lining cost was heavy, but against that they had no crucibles to pay for. Electric plant was certainly the cleanest they could wish. Apart from that, there were certain other advantages which could not be put into figures. The working conditions were certainly much better, for there were no ashes and no gaseous fumes. Regarding the heavy depreciation figure, of course, the makers of the furnace would insist that the figure shown was much too high, and that their furnaces would last longer than seven years; but in dealing with this plant one was always faced with the fact that fairly radical improvements would probably be made in the next few years, rendering existing plant obsolete.

TABLE IV.—*Cost of Operating a 750-lbs. Detroit Furnace.*

Alloy, 8 per cent. Lead Gunmetal.

Total operating time per day	9½ hrs.
Charge weight	750 lbs.
Melting time	55 min.
Casting temperature	1,200 deg. C.
Weight melted per day ...	3 tons (8 heats).
Power cost per ton	24s. 0d. at 1d. per unit
Labour per ton...	4s. 0d.
Electrode and lining cost per ton and maintenance ...	6s. 0d.
Interest at 6 per cent. and depreciation at 17½ per cent	18s. 3d. per ton.
Total cost	52s. 3d. per ton.

Melting practice had a considerable influence on the quality of the metal produced in bronze founding. Probably the most important factor was the speed with which melting was conducted Rapid melting was the main factor, and the furnace which would bring down the heat in quick time should be regarded with favour. During any

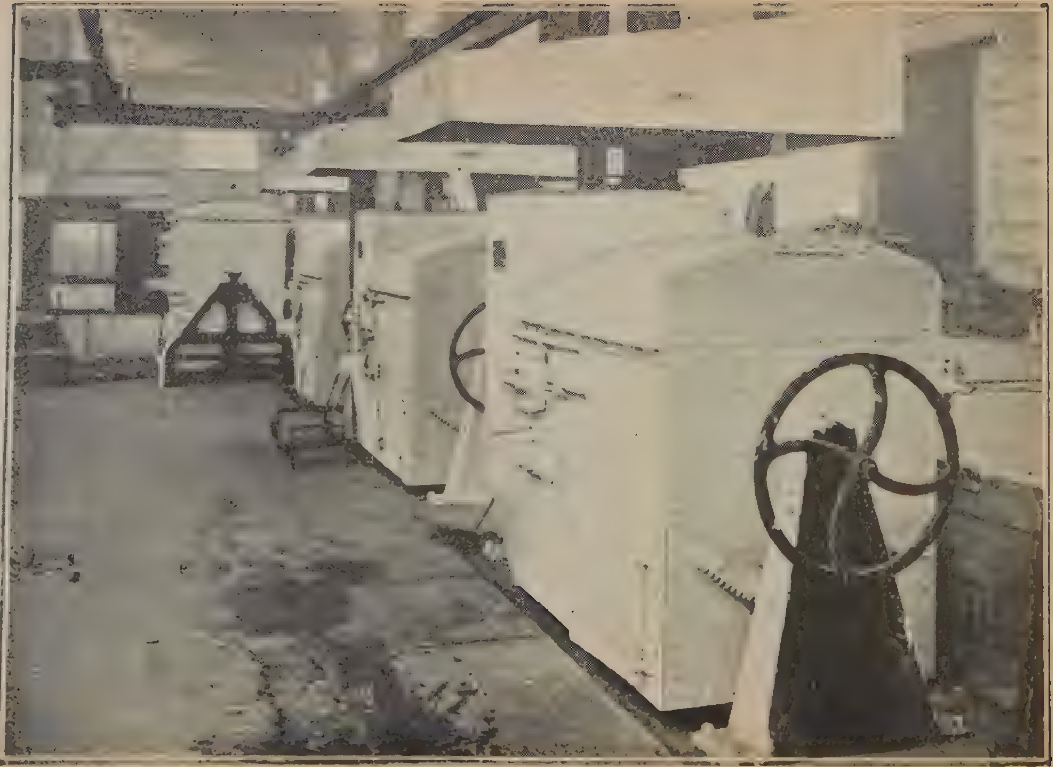


Fig. 1.—A Battery of Reverberatory Furnaces installed at the Works of Messrs. David Brown & Sons, Limited, Huddersfield.

commercial melting process a certain amount of oxidation was bound to take place, no matter what kind of fuel was used. He had never yet seen a melting furnace which had anything like a reducing or neutral atmosphere. There was always an oxide formation, and it was very difficult to get a truly reducing atmosphere. The longer the metal was exposed to the furnace atmosphere the greater the amount of oxidation. It was, of course, possible to effect some improvement by the use of de-oxidants, but it was better to avoid oxidation.

There was also the question of gas absorption in a bronze. It was obvious to presume that the metal which was longest in contact with the fuel would be liable to absorb most gas. There was a fallacy that the metal in the interior of a crucible was protected from gaseous absorption. He did not think that any material amount of protection against gaseous absorption was given by the ordinary crucible. The effects of oxidation and gas absorption were somewhat difficult to differentiate, and much research work was needed before it could be dogmatically stated which of the many troubles in bronze founding were due to liberation and absorption of gas. If one attempted bronze founding with dirty raw materials and with slow melting, coupled with exposure to the atmosphere, one was certain to encounter trouble. They had arrived at a stage when they could state with certainty that a high proportion of ingot copper in any charge would result in troubles due to gas liberation or gas absorption. This was now generally attributed to the practice of copper founders in leaving a fair proportion of oxide in the copper. This, of course, was done to enable them to cast a clean-looking ingot.

In alloys with a high percentage of tin, particularly if phosphorus was present, inverse segregation or tin sweat was a very valuable guide to the quality of the metal being poured. It could be safely said that with the ordinary alloys, where casting temperature and conditions were correct, no tin sweat should be seen on the surface, and it should be the object of every bronze founder to see that his metal conditions were such that no tin sweat appeared. He did not

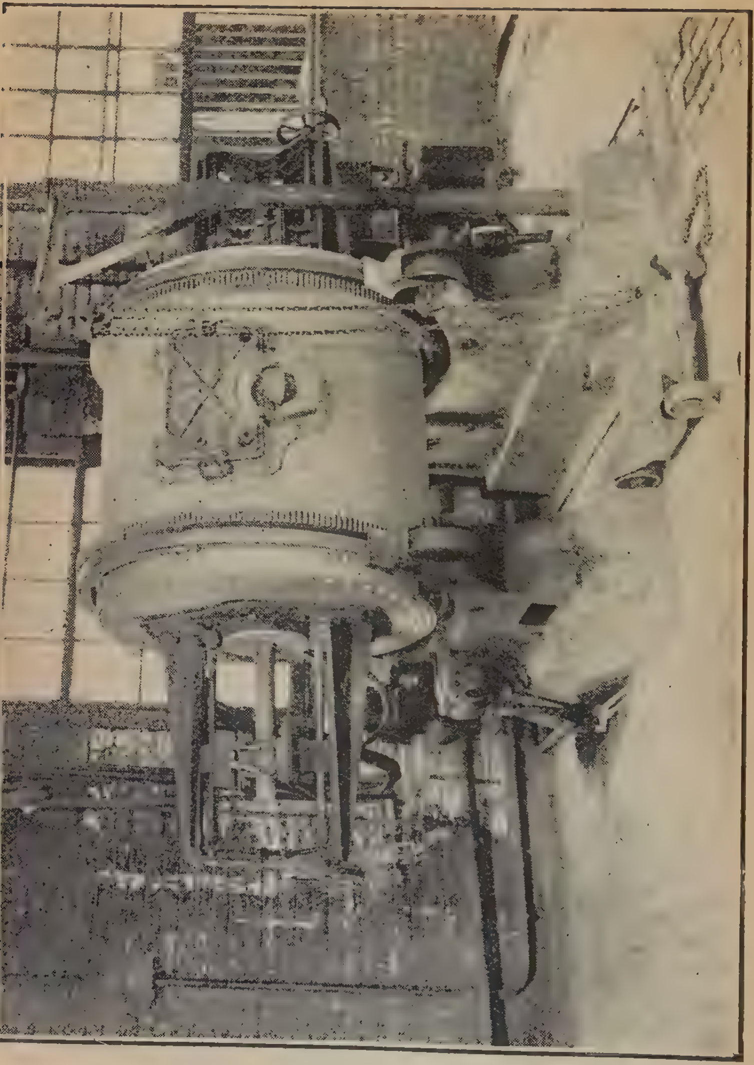


Fig. 2.—The Detroit Rocking Furnace.

insist that because a runner or riser had tin compound beads on it it was scrap, but it would be found that the general properties of the metal would not be the best of which the alloy was capable. The risers and runners should have a hollow surface. They should not be convex.

Mr. Rowe showed a fracture of a half-bearing sand casting. The fracture was obtained by squeezing the half bearing in a vice. Some might insist that such a fracture was entirely due to gas absorption. He could not agree, and he certainly thought that oxide inclusions had a serious influence.

Micro sections of several fractures were shown. In the first, films of oxide, which caused an intergranular fracture, could clearly be seen. The fracture would take place quite easily along these films. The second showed the same sample lightly etched. It could be seen where the holes were compound the high tin had disappeared, and the thin films running round each crystal boundary. The third showed more clearly some oxide inclusions in another sample. It showed slag inclusion, which resulted in a fracture at very low stresses.

To avoid such troubles, several standard rules should be observed. Whether one was melting in a pit-fire crucible or in a non-crucible furnace, one should make sure that the container was very well heated before charging the metal, to ensure rapid melting. This would not give low fuel consumption, but it was preferable in the long run. In the case of Admiralty gunmetal the temperature should be 1,300 to 1,400 deg. C. before any metal was added. It was the practice in his works to get the pot up to a white heat, to ensure rapid melting on the first heat. They also avoided as far as possible high percentages of a new metal. They preferred 25 to 30 per cent., unless they were using electrolytic copper. They also avoided as far as possible light scrap, and if they had any dirty scrap which had to be worked up, they always sand-blasted it, and melted it into ingots and refined it before using it in the actual charges for casting. They had tried a great many fluxes from time to time, but had found them more trouble than they were worth. They relied on a good covering of charcoal to prevent any surface oxidation when melting.

Apart from these questions of oxide and gas inclusions there were the questions of running conditions, casting temperature, and runners and risers. If they required castings of high strength and good physical properties generally, correct casting temperature was important, but it could not be considered by itself. It was not possible to give a definite casting temperature for any particular alloy, because a great deal depended on the size and shape of the casting, and the conditions under which the metal was being run. What really mattered, and what was rather difficult, was to find out at exactly what temperature the mould was filled. The ideal to achieve when casting evenly distributed sections was that the mould should be filled with molten metal at the same temperature. That was rather difficult; but a great many scrapped castings could be attributed to the mistake of having the metal in the mould much hotter at one point than another. In this matter they had a very easy guide in the grain size of the metal.

The grain size of every alloy under a definite standard set of conditions varied, of course, with the casting temperature. The higher the casting temperature, the longer the period of solidification, and the larger the grain size. If the casting were machined, one could nearly always tell the size of the grain without having to destroy the casting for that purpose. A great many troubles were due, for instance, to the metal being at the correct temperature when it entered the runner, but being too cold somewhere else. When casting an uneven section it was still more difficult to fill each part of the mould with metal of the correct temperature. It was necessary to see that the period of solidification in each section was such as would give a metal of good properties. The lighter sections of the mould should be filled with metal of a higher temperature than the heavier sections.

The grain size of any alloy was intimately connected with the strength of that alloy, and a great deal of useful work could be done by controlling the grain size, just as it was controlled in the heat treatment of steel.

Centrifugal Casting of Bronze.

Most of this work done by his firm was bronze or phosphor bronze for wearing surfaces, and he supposed that most of them were familiar with the general constitution of such alloys. The composition of such metals was fairly standard. They consisted of plain tin-bronze, with 11 to 12 per cent. of tin, and with or without a certain proportion of phosphorus. The idea in using phosphor bronze was to get a metal with mixed crystals—crystals of different hardness. In such metal the tin compound was the hardest, and its crystals were embedded in a soft alloy matrix. The theory was that these hard particles took the load and resisted the wear, while the soft metal bedded down and allowed the bronze to adjust itself to any inequalities of the surface against which it was working. Whether that theory was true in every detail he was not prepared to say, but certainly the friction of bronze, working against steel, was considerably lower than any other alloy which had been found, except white metal, which was too soft for these duties.

One or two impurities had to be avoided. Zinc should be kept out of the mixture. The effect of zinc was to increase the hardness of the softer portion, and thus lessen the difference between the hard and soft portions. Lead was a valuable addition if one could permit the low yield point which resulted, and the lower general physical properties. The lead formed soft pockets and softened the matrix, making a greater difference in hardness between the general body and the hard spots.

The effect of phosphorus on phosphor-bronze was generally understood. The general trend was for a lower content of phosphorus than was commonly used formerly. It was thought formerly that the hard particles of phosphide of copper were in general responsible for the good frictional qualities of phosphor-bronze, but recent research had shown that the hard particles of phosphide of copper were by no means as hard as those of tin compound, and that phosphorus had a serious effect on the shock strength of such alloys. They preferred tin to phosphorus as a hardener. It was also slightly better as regards wearing.

Phosphor-bronze had quite good physical properties, having a tensile strength of 18½ tons per sq. in., and an elongation of 30 per cent. when sand cast under the best conditions. Most of his firm's work was automobile worm wheel blanks. These were not easy bronze castings to make, particularly to secure sound metal in the centre. The roots of the teeth represented the very centre of the casting, and therefore, that portion of the casting which was likely to be unsound. In the old days they were faced with a considerable proportion of scrap, although some of the defects were not very apparent. They would readily appreciate the fact that the very heart of the casting was the most likely part to be faulty in the direction of porosity, and to overcome this difficulty of slight porosity they had cast these blanks with a chill round the periphery.

This method of casting improved matters considerably. It was certainly a decided improvement over a sand casting. Chilling the outside, however, had one or two disadvantages. It was liable to cause the outside portion of the wheel blank to be sound at the expense of the inner portion, and while a small amount of porosity and unsoundness in this position was not a very serious feature, it prevented them from lightening the design. Another disadvantage of chill casting was that the differential rate of cooling resulted in a structure which was not the best of which the alloy was capable.

Naturally, from chill casting with a ring on the periphery they progressed to casting these wheel blanks in a complete steel mould, except that it had a sand core. While this improved the properties of the alloy as regards structure and density, and general soundness, it proved hardly a commercial proposition. The chief trouble in attempting to die-cast phosphor-bronze was the difficulty of providing sufficient feed for the rapidly contracting metal, and they found that the temperature at which the metal had to be poured, and the temperature to which the moulds had to be heated, was such that they lost some of the advantages of chill casting, in that the grain size was larger than generally occurred in ordinary chill casting.

From that they proceeded to centrifugal casting. There were two considerable advantages in centrifugal casting. First, the smaller grain size. This was due to the fact that the metal was kept in a state of agitation during the whole period of solidification. Some people were inclined to attribute the good qualities of centrifugal casting to the fact that the casting was made in a steel mould; but the grain size was very different from that of an ordinary die casting. That, he believed, was due to the constant stirring up of the metal while it was freezing. The second advantage of centrifugal casting was that the feeding was automatic. They were forcing metal in to fill up the cavities during the whole period of solidification. The actual pressure developed in the process his firm was using was about 50 lbs. per sq. in. By this process they did away with the troubles of liquid contraction.

New Developments.

One of the most important items in bronze founding to-day was the present high price of tin, and the price was likely to remain high for some little time. A good many efforts had been made in recent years to find a substitute for tin, and one or two metals or alloys gave great promise of success. Americans, with their great fondness for nickel, were using a small amount of that metal in place of tin for most of their quantity production work in bronze. The standard phosphor-bronze such as was used for chill-cast bronze-bearings was now being made in the United States with between 1 and 2 per cent. of nickel, the tin content being cut down by 1 or 1½ per cent. He had recently received results of long-service wear tests with this bronze having the nickel content, and it certainly seemed from these results that the nickel had a definite advantage. The addition of nickel to bronze or phosphor-bronze raised the tensile strength and hardness. The nickel also appeared to give a higher fatigue strength in service.

Very good results had recently been obtained from some of the aluminium-nickel-copper alloys. These alloys had 7 per cent. of aluminium, and 5 per cent, of nickel, and the rest was copper, with a few small differences.

These alloys had been investigated in recent years, but they did not seem to have been adopted commercially except in one or two cases. Of course, aluminium bronze generally formed a strong temptation, and gave on test very high physical properties; but an ordinary aluminium bronze was very difficult to cast. It had been found that with a lower aluminium content and a practicable amount of nickel—4 to 5 per cent.—the difficulties in founding were very little, if any, greater than with ordinary bronze, particularly if silicon and manganese were added to the alloy. An alloy now with 0.4 per cent. of silicon, in addition to 7 per cent. of aluminium and 5 per cent. of nickel, was regularly giving tests of 35 to 40 tons, and had none of the disadvantages of manganese bronze as regards being easily corroded. It gave good working qualities, though not as good as phosphor-bronze, and their efforts were being directed to improving the bearing qualities of such alloys.

DISCUSSION.

Mr. Longden said that Mr. Rowe had shown that the cost of the ordinary pit fire furnace was remarkably low, and after all that was the criterion. While one could see the value of the electric furnace, one had to have some regard to the question of cost.

Mr. Dickie raised the question of the comparison of costs between the ordinary pit fire and the reverberatory furnaces—49s. to 29s.—which was £1 per ton of difference. One per cent. of difference on the melting loss would just save that. How did these figures come out?

Mr. Rowe said that that was a point they were very much afraid of when they put in reverberatory furnaces for bronze melting, and they had taken very careful tests. The melting loss with a reverberatory furnace was certainly no higher than with a crucible furnace. In melting phosphor-bronze cuttings into ingots they had a melting loss of 0.8 per cent., and 0.3 per cent. when melting ingots for casting. That figure was, of course, the total metal loss, and was taken from the total stock returns to the store for each battery of furnaces. One could not melt a ton of metal and then weigh it. These figures were over long periods with two types of furnaces. There was no reason why the reverberatory furnace loss should be higher, because any oxidation that took place took place just the same in a crucible furnace. Provided one kept the oxidation loss low, there was no reason why the melting loss should be higher. In actual practice they had never found the difference in melting loss to be appreciable. That was their fear when they first installed these furnaces. They put in a big furnace first, and watched it carefully for twelve months before installing the others.

MR. F. HUDSON said that three points dealt with by Mr. Rowe had interested him very much. The first was the comparison of melting costs. In working out the cost of these various furnaces the actual melting cost was certainly of value, but in his opinion it was not the most important point in a foundry. The melting cost alone was no criterion to the actual foundry efficiency. For instance, cheap melting costs might result in an increased yield of defective castings, with a consequent reduction in general efficiency. With the Detroit electric furnace the melting cost was in fair comparison to the melting cost with the ordinary pit crucible fire, yet the melting loss in the electric furnace would be less than in ordinary crucible melting. Another important point in electric melting was that the metal, in his opinion, had better physical properties. Gas penetration was less, and the need to ingot the raw material before final remelting was unnecessary. All these factors were bound to have a definite financial value. He was very much interested in the Detroit electric furnace because at the present time his own firm, Messrs. Glenfield & Kennedy, Limited, were about to place an order for one of these units. They had considered a reverberatory furnace, but thought that with it gas penetration would be as bad as with the crucible furnace, or worse, and they wanted to overcome gas penetration as much as possible. This point should be considered.

The other point he wished to raise was in connection with grain size. Mr. Rowe had stressed the fact that it was most important to control the grain size in casting, and he would like further to stress that point. His firm's largest output was in manganese bronze, and they made a daily practice of taking a micro-section of every heat and rejecting the material if the grain size was over a certain limit.

Aluminium Bronze.

Regarding Mr. Rowe's later remarks about aluminium bronze, his firm had been doing tests with that material. The compositions were just the plain aluminium-copper-iron alloys, and considerable trouble was experienced in melting and casting. When these factors were eliminated the resulting alloy was remarkable in its properties. They could get a tensile strength of 35 tons per sq. in., with an elastic limit of 18 to 21 tons per sq. in., with 30 per cent. elongation on 2 in., and an Izod impact test of 40 ft. lbs. In manganese bronze although a tensile strength of 35 tons per sq. in. could readily be obtained, the elastic limit was only about 14 tons per sq. in., with an impact test of about 30 ft. lbs. Comparison of these test figures showed the remarkably improved torsional and fatigue resisting properties of aluminium bronze.

Mr. Rowe replied that in regard to the point raised about melting loss, when his firm were considering whether to put down reverberatory or electric furnaces, they had to take into consideration the fact that the greater part of their work was in tin bronze. The melting loss was never great with tin bronze. He did not think the Detroit furnace showed any advantage in this respect. As regards gas absorption, he did not think there would be as much difference between the electric and the reverberatory furnace as Mr. Hudson had suggested. He was interested to hear that there was a bronze foundry in this country that was putting in a Detroit electric furnace, as it was a type that was doing good service in the United States. The costs of melting were not lower than with the pitfire furnace, but against that they had the advantages of no ashes and better working conditions. With reference to the remarks made about aluminium bronze, the difficulties of founding were very great, but if the aluminium content was brought down to about 7 per cent. and nickel was added, most of these difficulties would be overcome, and they would get as good if not better physical properties. Work on this group would be well repaid.

Chills and Grain Size.

Dr. Hyman said he wished to associate himself with Mr. Rowe's remarks in connection with the production of sound castings in copper-tin alloys. It was better to have the melting conditions correct than to alter the chemical composition of the alloy. It was quite common among foundrymen when they were in difficulties to alter the composition rather than devote more attention to the melting conditions. With reference to the grain size on the castings shown, he would like Mr. Rowe to explain why in chilling the sand casting one got a coarser grain size next to the chill. One would expect a finer grain structure. This was also borne out in the castings which were made in an automobile worm wheel blank chill mould. These castings all showed a coarse grain size. Had Mr. Rowe tried the effect of heat treatment on any of these coarse grain structures? Mr. Rowe had made no remarks about the actual costing with the centrifugal process. Did that process increase the price of this casting in proportion to the better mechanical results obtained? He was interested in the use of nickel in these alloys. There was no doubt that nickel produced its good effect by causing a finer grain structure. It was possible by using some other high melting-point metals to get the same effect.

Mr. Rowe replied that the large grain size of the die casting was due to the fact that it was necessary to cast at a very much higher temperature than in the case of a centrifugal casting. This increased the period of solidification, so that the casting would feed itself. Similar remarks applied to castings with a chill on their periphery. It was necessary to cast at a higher temperature than in the case of a plain sand casting, which produced the large grain size. He was afraid that heat treatment of bronze was of very little value for bronzes that had to stand wear. The effect of heat treatment was to take the biggest part of the tin compound into solution, thus spoil-ing that hard and soft structure which was an essential for wearing qualities.

Mr. Arnott, moving a vote of thanks to Mr. Rowe, said he would like to commend his Paper to those members of their own Institute who were always asking for practical Papers. They always had difficulty in getting Papers from the people who were actually doing the job.

Newcastle-on-Tyne Branch.

SOME FURTHER NOTES ON OIL-SAND AND MOTOR CYLINDERS.

By Walter West (Member).

Further to any previous notes that have been written by the author, it might be as well at the outset to state that the results here given represent the beginning of an extensive series of practical experiments to explore the nature and use of all media which might be of service to the foundryman in an oil-sand mixture. There are several factors which qualify a sand mixture for service, and these will vary according to the needs that arise in any given practice. Under certain circumstances it becomes necessary to add proportions of naturally-bonded sand where the work to be carried out is excessively large or the conditions of casting so severe that artificial bonding would be insufficient to hold up against the heat, erosion and pressure of pouring. In these notes, however, *no consideration is given to the use of clay additions* in any form to a mixture of oil sand.

Rosin as an Agglomerant.

The more important features required of an artificially-bonded mixture can be enumerated as follows: The green bond strength, the strength of the dried core mixture and permanence of the bond. In motor-cylinder work, the greatest difficulty has been to produce a mixture having the requisite strength in the green state to enable cores to stand to some of the complicated and intricate shapes which are becoming much more common with the advanced design of cylinders and their respective head castings. To obtain the maximum of this property, two items are of great importance—first the ingredients composing the mixture, second the mixing treatment to which the mixture is subjected during preparation. In the first instance, previous articles by the author give the main materials which contribute largely in this direction. In addition to these, of late attention has been focused upon the use of rosin as a useful medium for increasing the green bond strength of an oil-core mixture, although this material has been known and used for long years as an addition to naturally-bonded sand-mixtures with satisfactory results. Rosin is obtained from the distillation of oleoresins wherein turpentine spirit is collected and the residue in the vessel when cold sets to the hard substance called rosin. There is a little difference between rosin and some of the resins which exude from trees, but this affects the varnish maker rather than the foundryman owing to its composition and dark colour, which rates the price at a lower figure than the resins.

Rosin is comparatively cheap, and where it is mixed with the right ingredients shows results which are worthy of note. It melts at 120-135 deg. C. and is soluble in most solvents, except water; it can, therefore, be dissolved very conveniently in linseed oil when it is mixed as an ingredient to a sand mixture. Resins and rosins may be used as resinates, *i.e.*, lead, manganese and cobalt being frequently used to accelerate the process of oxidation in varnish making, so that if similar reaction takes place at elevated temperatures it would suggest their usefulness in a core mixture to further expedite the drying process of oil-sand cores where quick process is essential; this point, however, will be the subject of another Paper at a later date.

The very convenience of making additions of rosin dissolved in oil as an ingredient of an oil-sand mixture raised the query whether a greater benefit would be derived by its addition in this form, or as a dry powder. To this end experiments have been conducted to effect some result.

Test Bars Used.

The commonly used 12-in. × 1-in. × 1-in. core box was chosen in which to make the standard core, and the core so made carefully pushed to the edge of a piece of plate glass until the end of the core protruded over to such a length that the weight of the end exceeded the strength of the green sand and broke off. The broken piece was measured and its length stood as a comparative figure to other mixtures.

The mixtures used in the experiments were made in a small experimental "Torrance" mill which has one light muller and plough by which a thorough mixing is obtained. The muller is light in weight and the pressure on the roller can be adjusted at will. To a standard core mixture progressive amounts of rosin were added in two forms:—(a) With rosin dissolved in linseed oil, and (b) with rosin as a dry powder, the following results being obtained:—(1) Effect of (a) rosin dissolved in oil (Table I) and (2) effect of (b) rosin powdered in the dry (Table II), upon the green-bond strength.

TABLE I.—"a" *Series of Experiments.*

Percentage of rosin.	Green-bond strength. Per cent.		
0.15	1.10	1.10	1.15
0.3	1.10	1.15	1.10
0.45	1.10	1.15	1.10
0.60	1.10	1.15	1.10
0.75	1.10	1.15	1.10
0.90	1.25	1.25	1.25
1.05	1.25	1.30	1.25
1.20	1.25	1.30	1.25
1.35	1.30	1.30	1.30
1.50	1.35	1.40	1.40

TABLE II.—"b" *Series of Experiments.*

Percentage of rosin.	Green-bond strength. Per cent.		
0.15	1.0	1.0	1.1
0.3	1.0	1.0	0.95
0.45	1.0	1.0	1.0
0.60	1.0	1.0	1.05
0.75	1.10	1.10	1.0
0.90	1.20	1.25	1.25
1.05	1.20	1.30	1.20
1.20	1.40	1.40	1.50
1.35	1.60	1.60	1.65
1.50	1.60	1.65	1.70

A graphical representation (Fig. 1) of these results shows a distinct lag at the beginning of each series where the green-bond strengths of the mixture differ but little; when the additions, however, reach 0.90 per cent. in both cases there is a

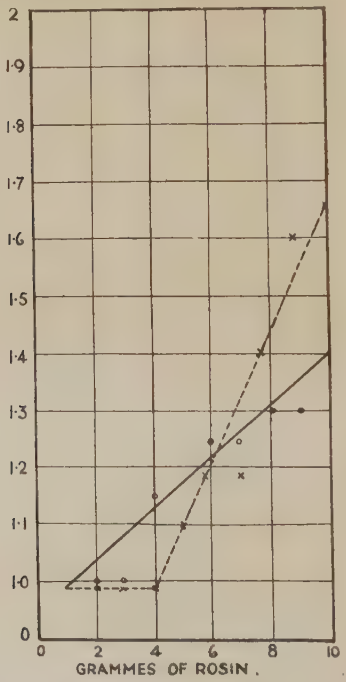


FIG. 1.—CURVES SHOWING DIFFERENCE IN GREEN BOND BETWEEN SAND WITH ROSIN ADDITIONS DISSOLVED IN OIL (FULL LINE) AND SAND WITH POWDERED ROSIN ADDITION (DOTTED LINE).

marked increase in the strength which rises more rapidly as the higher percentage additions are made in the dry state. This may possibly be due to the influence of the bulk of dry powdered rosin exerting a frictional resistance between the sand grains, in which case it might be reasonable to expect that the addition of any dry impalpable powder not injurious to the final quality of the core might produce a corresponding increase in the green-bond strength of the mixture. In any case, it would be difficult to find a substance more suitable than powdered rosin for this end, having such a blend of properties, so convenient for the production of the ideal type of hard smooth faced core with the necessary permeability. To obtain evidence that dry powder rosin when mixed with oil in a sand mixture exerted a physical effect over and above that obtained when using it dissolved in oil, many experiments have been carried out, two only of which will be sufficient to illustrate the point

Taking the same progressive amounts of dry powdered rosin in each case—two quantities of oil additions are shown in proportion to the quantity of sand, no other additions being made. The mixtures were made in an experimental "Torrance" mixer for exactly the same period of time for each.

When the proportion of oil to rosin or sand is the smaller as in the first series, the green bond strength of the mixture rises corresponding to the addition of powdered rosin, as shown by the full line curve in the graph, Fig. 2, the sand

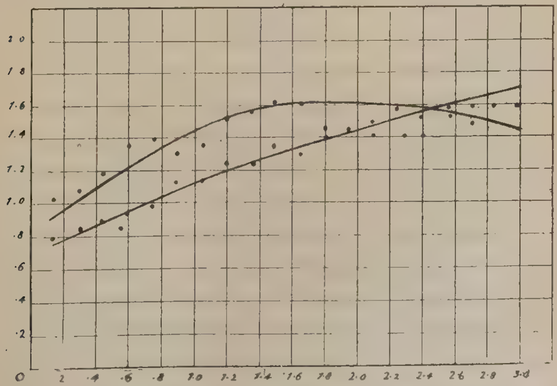


FIG. 2.—EFFECT OF ROSIN ADDITIONS TO OIL AND SAND IN RELATION TO GREEN BOND STRENGTH.

darkens in colour and towards the maximum percentage addition shown, the mixture sticks very badly to the core box, making it very difficult to produce a good draw. It was particularly noticeable, also, that the hardness of the dried core increased as the increase of the rosin additions which would indicate a very useful property of this substance, when hardness and strength in the dried condition is required of a sand core.

In the second series where the proportion of oil to rosin or sand is much greater, the results obtained show a very much quicker and greater rise in the green bond strength of the mixture as the rosin additions increase until a maximum is reached at 1.6 per cent. when the strength somewhat decreases. Up to this maximum the sand mixture was good to work and left the core box in the usual way without sticking, but above this percentage, the mixture became sticky and eventually unworkable.

TABLE III.—*Rosin added dry* (1½ *lbs. sand to* 5 *c.c. oil*).

Per cent. rosin addition.		Green-bond strength. Per cent.
To oil.	To sand.	
	0	0.75
22.5053	0.15	0.80
45.0106	0.30	0.85
67.5159	0.45	0.90
90.0212	0.60	0.95
112.5265	0.75	1.00
135.0318	0.90	1.15
157.5371	1.05	1.15
180.0424	1.20	1.25
202.5477	1.35	1.25
225.0530	1.50	1.35
247.5583	1.65	1.30
270.0636	1.80	1.40
292.5689	1.95	1.45
315.0742	2.10	1.40
337.5795	2.25	1.55
360.0848	2.40	1.50
382.5901	2.55	1.55
405.0954	2.70	1.55
427.6007	2.85	1.60
450.106	3.00	1.70

The Effect of Mixing and Milling Upon the Grain Size of a Sand Mixture.

The general trend of foundry thought is to conclude that oil-sand mixtures are best produced in some type of mixer which will not break the grains of the sand, and hence there is offered on the market the various types of paddle mixer or some design very similar in principle. It is, however, a conclusion which has been generally accepted rather from the makers of the machinery than a result of experimental work. Foundrymen for many decades have been aware that the application of work in the manner of treading with the feet causes a sand mixture to be considerably tougher to the feel and better to mould into shape than when mixed with the shovel only. The explanation is, that the work of treading causes a more intimate and evenly distributed contact between the grains of sand and the clay bond. In a similar way, the delicacy and

TABLE IV.—*Rosin added dry* ($1\frac{1}{2}$ *lbs. sand to* 17.75 *c.c. oil*).

Per cent. rosin addition.		Green-bond strength. Per cent.
To oil.	To sand.	
	0	0.85
0.605	0.15	1.05
1.211	0.30	1.10
1.817	0.45	1.20
2.423	0.60	1.35
3.029	0.75	1.40
3.635	0.90	1.30
4.240	1.05	1.35
4.846	1.20	1.50
5.452	1.35	1.55
6.058	1.50	*1.60*
6.663	1.65	*1.60*
7.269	1.80	1.45
7.875	1.95	1.45
8.4814	2.10	1.50
9.089	2.25	1.40
9.692	2.40	1.40
10.298	2.55	1.50
10.904	2.70	1.45
11.510	2.85	1.55
12.116	3.00	1.55

frailty of the shapes required in the majority of cores for motor cylinders call for the highest degree of strength from the sand mixtures, and it is found in the preparation of oil-sand mixtures that the application of work in the form of a moving weight upon the sand produces a greater strength in the mixture. The diagram below shows the difference effected by three different types of sand mixers using three standard sand mixtures.

Series 1 (Fig. 3) illustrates the degrees of green bond strength obtained from the same mixture but mixed (1) an old type of Fordath paddle mixer; (2) the latest type of double Simpson muller mixer; and (3) an ordinary type of mortar mill with two plain mullers.

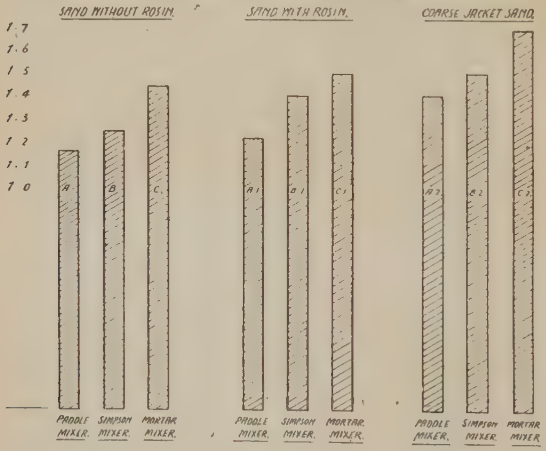


FIG. 3.—GREEN BOND STRENGTH OF OIL SAND MIXTURES.

Series 2 (Fig. 3) shows the results obtained from similar experiments as Series 1, but with the addition of 0.50 per cent. rosin, which explains the total increase in strength of the mixture.

Series 3 is of a very interesting nature on account of the general idea that a coarse grain sand is necessarily weaker than one of fine grain —this is not so, for in these experiments a very coarse Leighton Buzzard sand was mixed with

TABLE V.—*Sieving Tests on Various Sands.*

Shore sand mixture.	Size of Sieve (meshes to sq. ins.).										
Mixture from	10	20	30	40	50	60	70	80	90	100	Fines.
		%	%	%	%	%	%	%	%	%	%
Paddle mixer	—	0.30	1.5	3.8	32.5	41.0	15.5	1.70	2.7	0.20	0.70
Simpson mixer	—	—	0.2	5.2	34.7	39.5	12.9	1.40	4.2	0.10	1.30
Mortar mill	—	—	0.5	3.3	16.5	47.5	23.5	1.70	5.2	0.20	1.50
Shore sand before use.. ..	—	—	0.32	1.59	21.4	46.3	23.3	1.52	4.31	0.39	1.42

TABLE VI.—*Sieving Tests on Coarse Sands.*

Coarse sand mixture.	Size of sieve (meshes to sq. ins.).										
Mixture from	10	20	30	40	50	60	70	80	90	100	Fines.
	%	%	%	%	%	%	%	%	%	%	%
Paddle mixer	2.8	16.75	25.95	6.3	12.16	19.0	10.85	1.97	2.65	0.27	0.93
Simpson mixer	3.37	19.0	27.0	4.7	6.7	23.0	11.4	1.20	2.75	0.17	0.65
Mortar mill	3.80	16.5	28.0	5.0	7.5	22.6	15.7	0.05	0.10	0.07	0.78

equal quantity of shore sand, and although the quantities of the artificial bond added were slightly different from the previous mixture, yet this was not enough to account for the very marked increase in green bond strength obtained. The explanation is no doubt to be found in the larger surface area which is exposed around the larger grains for the bonding material to cover, which would be reinforced in the interstices by the finer grained sand.

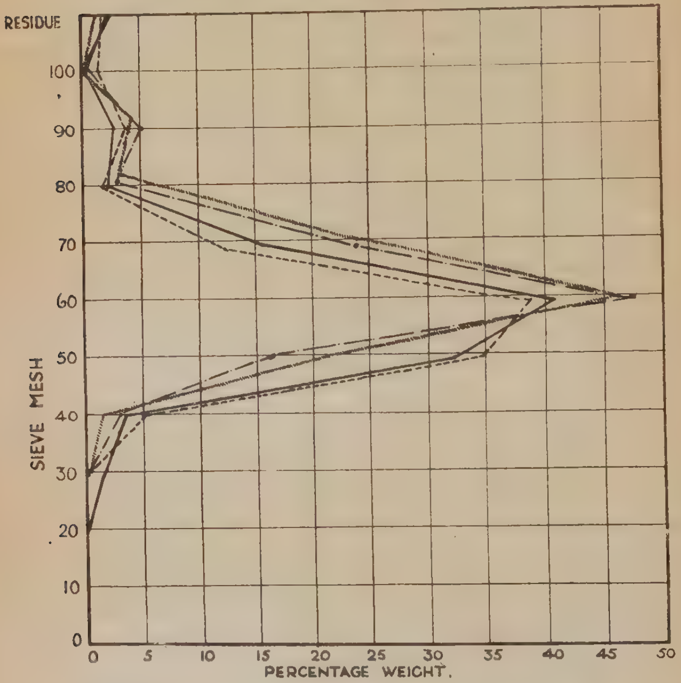


Fig. 4.—Effect of Milling upon the Grain Size of Various Sands. The Paddle Mixer is indicated by a Full Line; the Simpson by a Dotted Line; the Mortar Mill by a Dot and Dash Line; and the Unused Shore Sand by a Hatched Line.

In all the series it will be noticed how the strength of the sand is increased in proportion to the work applied during mixing.

The point now arises, to what extent is damage done to the grains of the sand when subjected to

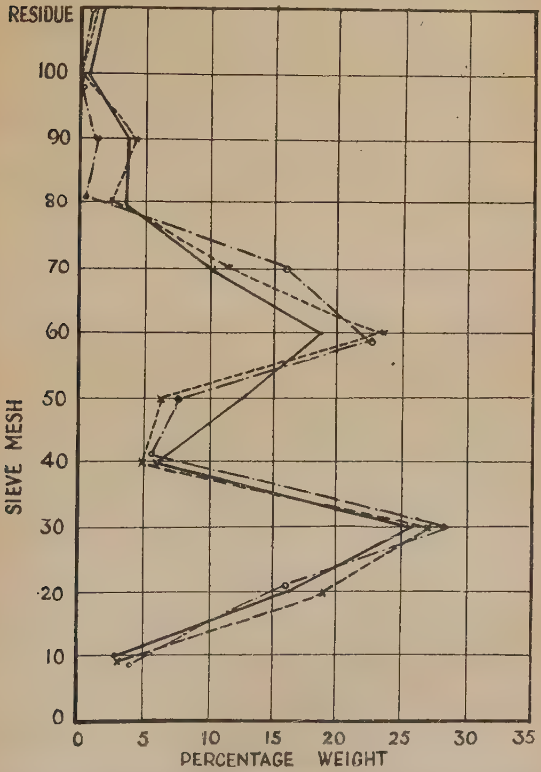


Fig. 5.—Effect of Milling on Coarse Sands. The Mode of Expression is that indicated in Fig. 4.

the weight of the heavy rollers. By taking Series 3, where the coarse-grained sand was used, a much better opportunity will be afforded of measuring more accurately than in the case of the other mixtures. To this end samples of the sand mixture after each treatment were taken and ignited thoroughly to burn off the volatile bonding material, after which 100 grammes of the ignited sand were put through a set of standard sieves, and the amount of sand retained on each size of sieve weighed and expressed as percentages. The graphs shown in Fig. 4 express the results. It will be seen that there is very little difference in the grain size of the three mixtures, the greatest degree of difference occurs between the sieves 60 and 80, but is not disturbing.

The lower grain sizes are of an equal regularity which is a definite proof that grinding of the sand grains does not take place. Where the dry sand is allowed to be milled for any length of time without the additions of oil, etc., necessary for the mixture, it is to be expected that a breaking-up of the grains will occur. It is the author's opinion that the additions of oil, molasses, etc., act as a lubricant and a preventative against the trouble generally anticipated.

In Tables V and VI are the figures of two experiments, using, in the first place, shore sand only in the mixture, and in the second a mixture of equal quantities of coarse Leighton Buzzard and shore sand.

These results, stated graphically in Figs. 4 and 5, are very interesting, and illustrate the point claimed with greater distinction than the tables of figures. Particular note should be made of the results obtained from the shore sand mixture—comparing the trend of the curves from each type of mixture with that of the unmilled shore sand. The results here given are entirely reliable, representing a mean of many trials, at the same time being actual results obtained.

East Midlands Branch.

SOME METHODS OF PRODUCTION IN A MODERN MALLEABLE IRON FOUNDRY.

By H. J. Beck (Associate Member).

It is not proposed to deal with the metallurgical side of this subject, that being in the hands of an efficient laboratory staff, which controls the analysis, and gives the foundry suitable metal at high temperature from ten air furnaces. Six of these are hand-fired with 5- or 6-ton charges, and the remaining four by pulverised fuel, two take 10 to 15 tons per charge, and two others 15 to 20 tons per charge. It is proposed, however, to detail the methods of moulding that have enabled the Leys Company to produce over 10,000 tons of malleable castings during the last 12 months.

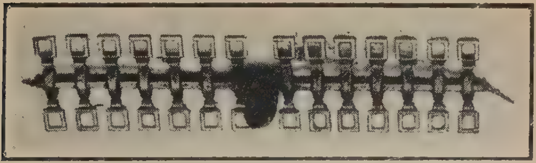


Fig. 1.—One-third Box: 0.025 lb. per Casting.

All the samples illustrated are machine moulded, and are fairly representative of about 75 per cent. of the total output.

Types of Machines Used.

Most of these are made at the plant, with the exception of the sandslingers. The oldest type is a hand-squeeze (Farwell). This has a simple saddle top with hand lever and balance weight, and is used for very light work with intricate joints, or short-order work which would be too expensive to mount on pattern plates. For this machine, runners and feeders are attached to patterns which are made in brass, and the moulds are made in snap flasks from an oddside which may be made from ground red sand, doped with waterglass or silicate of soda, gutta-percha, plaster of Paris, or val-de-travers.

Air squeeze machines, of which there are over 100 in use, are fitted with a cylinder having a bore of 8 in. and a stroke of 6 in., with a lift of approximately 5,000 lbs. One squeeze is generally sufficient for one mould. They are fitted with air vibrators to assist in drawing patterns, and with a blow-valve for cleaning. They work at 100-lb. pressure.

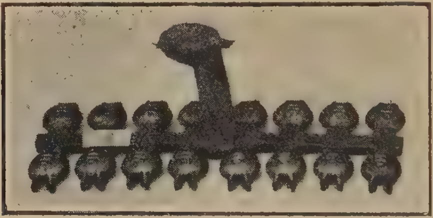


FIG. 2.—ONE-THIRD BOX: 0.033 PER CASTING.

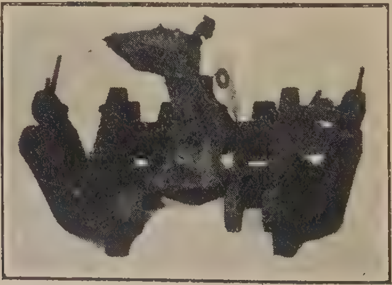


FIG. 3.—ONE-HALF BOX: 2.5 LB. PER CASTING.

Squeeze jolt machines, of which there are 18 in use, are a combination of squeeze and jolting operations. This method is very useful when deep drags and shallow copes are used, and castings of unequal contour may be made without the use of shaped follow boards.

Jolt ram.—These machines are invariably used in pairs for twin plates, and have a 4½-in. bored cylinder, with a 2¼-in. stroke. Four to six jolts are generally sufficient for each mould. These, too, are fitted with air vibrators and blow valves, whilst the lifting capacity is approximately 1,500 lb. The moulds are turned over on the pattern boards or plates, the usual turn-over operation by the machine being too slow, and a source of trouble by wear from sand on the machine slides.

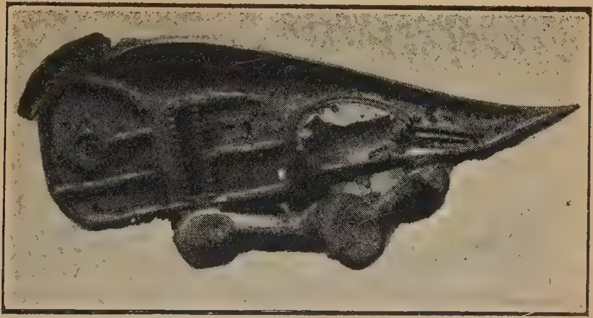


Fig. 4.—Full Box: 10 lb. per Casting.

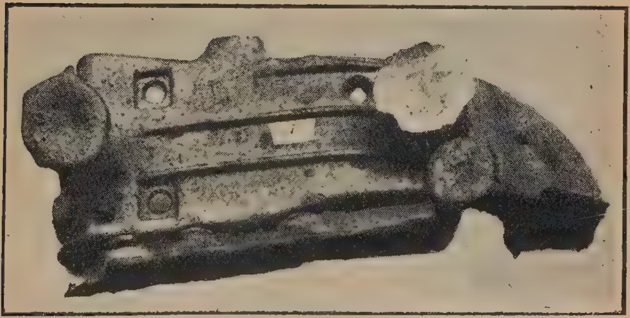


Fig. 5.—Full Box: 20 lb. per Casting.

Sandslingers.

These machines are driven by electricity and travel into the sand pile under their own power, collecting the sand from the floor by means of a left and right-hand cutting screw conveyor, which conveys the sand to the centre of the machine, where it is lifted by means of a bucket elevator, and deposited on the screen of an oscillating riddle. The sieve is arranged and constructed so that scrap, core, etc., which may be in the sand, work down into the chute, and from thence into the scrap box, which is mounted on the main arm.

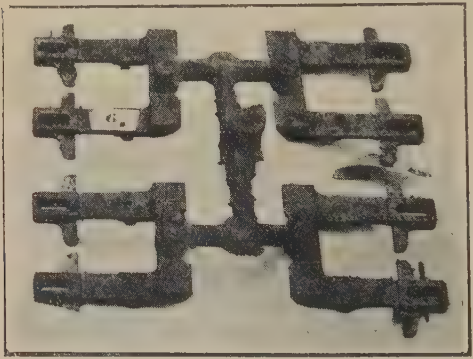


Fig. 6.—Full Box: 5 lb. per Casting.

The riddled sand is conveyed by the oscillating sieve into a hopper mounted on the impellor arm above a belt that conveys the sand into the impelling head, which discharges the sand with centrifugal force into the moulding box. The ramming capacity can be regulated by the speed it is fed into the sand pile. The impelling head has a 9-ft. radius, right and left-hand cutting screw conveyor is 11 ft. wide, the machine operates in a bay of at least 15 ft. wide and 200 ft. long. The moulding boxes used have bars cast-in, in the form of a grid, 2 in. deep. They are not flat, but are suitably spaced so as not to foul the runners and feeders.

It is now proposed to describe the samples illustrated in Figs. 1-19, and each one will be dealt with, mentioning type of machine on which it was made, whether made in snap flasks or iron moulding boxes, material patterns are made of, methods of feeding and running, knocking off, etc.

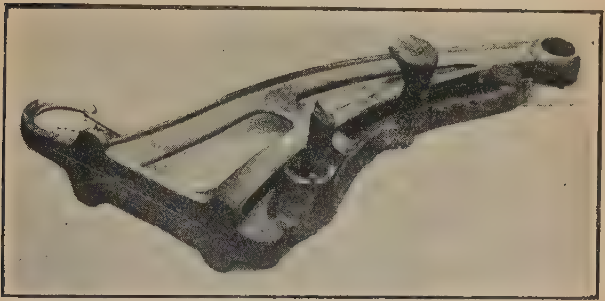


FIG. 7.—ONE-HALF BOX: 6 LB. PER CASTING.

Fig. 1 represents one of the smallest castings made that requires a core. There are 84 of each in one mould, a snap flask, 15-in. × 12-in., having a cope 4 in. deep, and the drag 3 in. deep. Each core must be placed in position separately and the fitting of this link must not vary beyond $\frac{1}{64}$-in., or it is rejected. This sample, illustrated in Fig. 1, has not been cleaned in any way whatever, and is just as it came out of the mould, it is $\frac{1}{3}$ of a complete mould. The patterns are

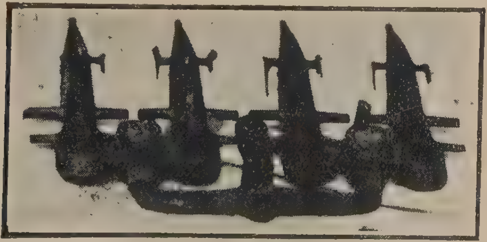


FIG. 8.—TWO-THIRDS BOX: 1 LB. PER CASTING.

made of brass, and soldered to a brass runner bar. Three sprays of patterns are then bedded into the drag-half of a mould, and then gutta-percha

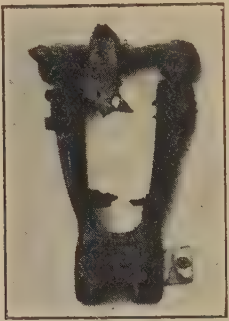


FIG. 9.—ONE-HALF BOX: 4 LB. PER CASTING.

is bedded on, thus forming the oddside, and the job is ready for work on the hand-squeeze machine.

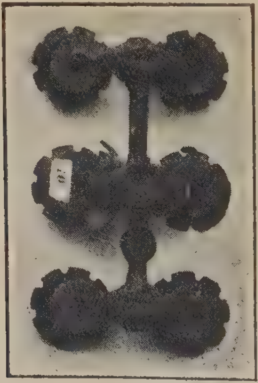


FIG. 10.—FULL BOX: 1.75 LB. PER CASTING.

The casting shown in Fig. 2 is produced in the same way, but has no core. It has an irregular joint line, and two fine projections inside the lip, which must be smooth and good. There are three sprays in a box.

Fig. 3 represents a heavier type of casting, normally made on the Farwell machine in a 15-in. × 12-in. snap flask, with two sprays in a box. There is one dry-sand core per casting. Other slots leave their own core without sprigs or nails, which demands neat tucking and ramming. The patterns are of cast iron made in a plaster odd-side.

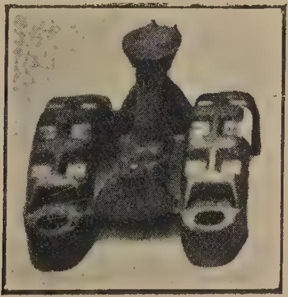


FIG. 11.—ONE-HALF BOX: 2.5 LB. PER CASTING.

Fig. 4 is a type of agricultural work made on a hand-rammed stripping machine in iron boxes of 20 in. × 12 in. × 4 in. Twin machines are used, making cope and drag simultaneously. Iron patterns stripped through a cast white-metal plate are used owing to the irregular contour of the joint. Fins are placed on various parts of this casting to prevent hot cracks or pulls. There is only one dry-sand core carried in this casting.

Another type of agricultural work of similar design to Fig. 4 is shown in Fig. 5. It is mounted on a cast white metal plate, and is made in a snap flask measuring 24 in. × 11 in. × 8 in. deep. Wrought iron binders are used in each half mould. The feeders, one of which is closed to prevent wasting metal, are removed whilst still hot to prevent cracking.

The air squeeze machine, which was first installed about 18 years ago, is used for snap flasks, ranging from 15 in. × 12 in. to 24 in. × 12 in. up to 12 in. deep. The patterns may be made of wood, brass or aluminium on either $\frac{1}{8}$-in. steel plates, $\frac{3}{8}$-in. aluminium, or 1-in. hard wood boards. The patterns are registered on each side of the plate or board. Perforated malleable iron bottom plates are used in connection with all the air squeeze machines, as the cope and drag are pressed at one operation. All pattern plates are fitted with compressed air vibrators of different sizes, so that it is seldom necessary to rap them. Two interchangeable flasks are used, one being rammed up whilst the other is being cored and closed. Cast-

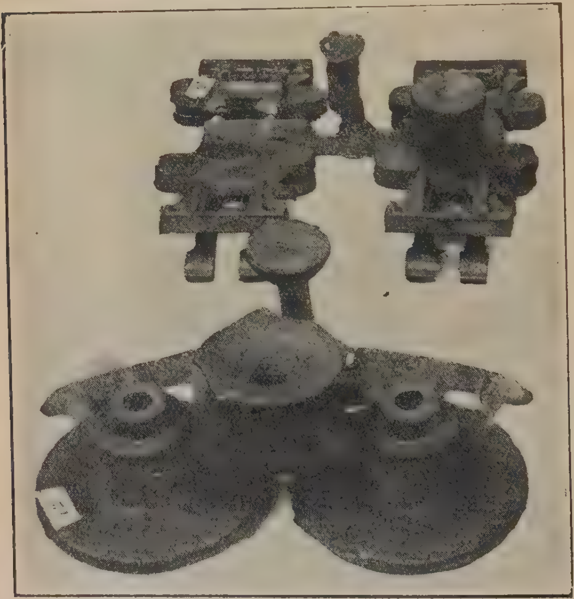


Fig. 13 (above).—Full Box: 2.5 lb. per Casting.

Fig. 12 (below).—Full Box: 7 lb. per Casting.

ings made on these machines vary in weight from 2 lbs. to 20 lbs. per box.

A light casting for the motor industry with an irregular joint line is shown in Fig. 6. There are eight brass patterns in a box made from hardwood board, and there is one core per casting.

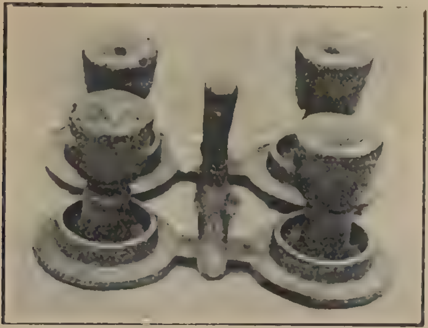


FIG. 14.—FULL BOX: 3 LB. PER CASTING.

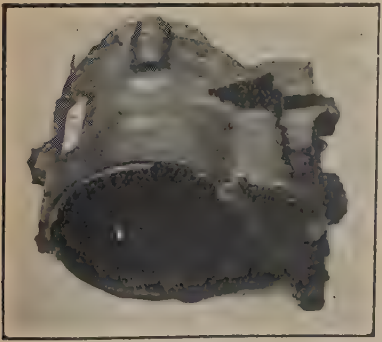


FIG. 15.—FULL BOX: 9 LB. PER CASTING.

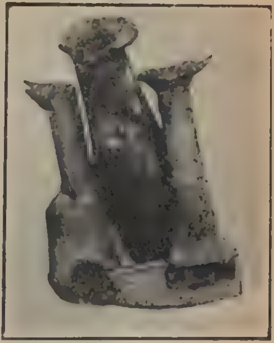


FIG. 15A.—FEEDERS, FOR THE CASTING SHOWN IN FIG. 15.

A larger casting is illustrated in Fig. 7, but it is still on the light side. The extra piece cast on

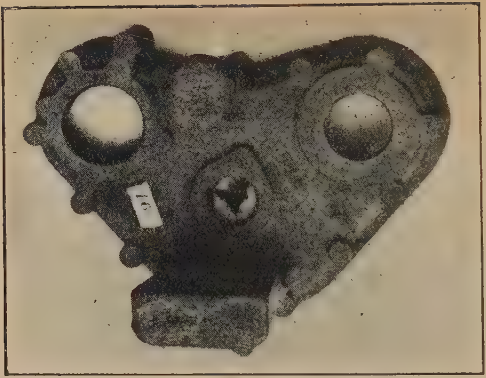


FIG. 16.—FULL BOX: 12 LB. PER CASTING.

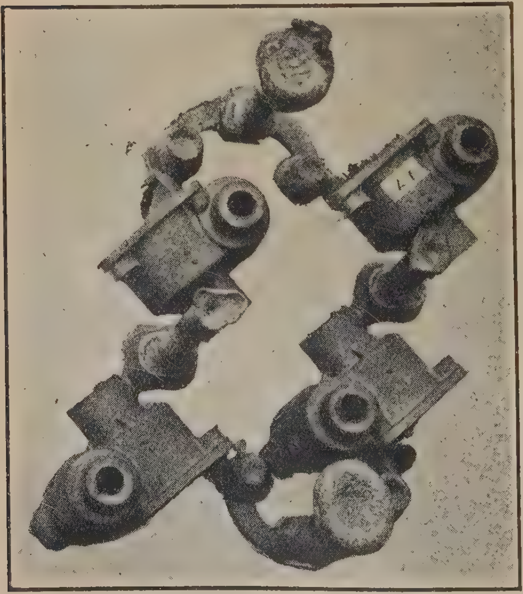


FIG. 17.—FULL BOX: 7 LB. PER CASTING.

to prevent the end of scroll jarring off when runners are removed cold is worthy of note. This casting is made from a cast aluminium-plate. There are two castings per box.

A type of agricultural casting of which the Leys concern makes about 100,000 castings per year is shown in Fig. 8. Probably there has been about this quantity made from this particular pattern plate. There are six patterns on a cast aluminium plate, and it carries one core per casting.

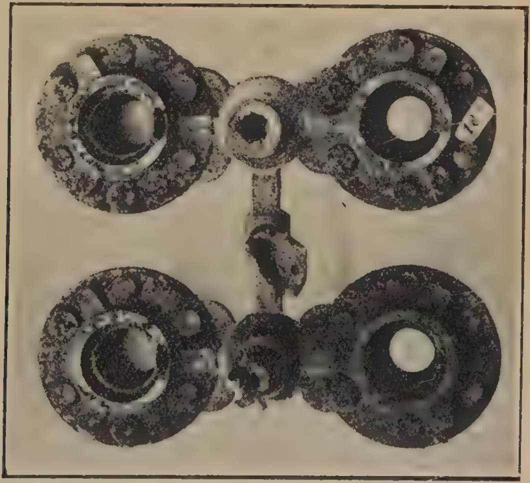


FIG. 18.—FULL BOX: 7 LB. PER CASTING.

Another type of chain link used very extensively is shown in Fig. 9. This pattern is seldom out of production, a man and boy making approximately 1 ton per week. There are two cores per casting and two castings per snap flask. An aluminium pattern on hard-wood board is used.

Fig. 10 shows an adjusting nut for the motor trade. For its making aluminium patterns mounted on steel plate are used. Two cores are carried per casting, and there are six castings per box. The joint line of this mould is away from the teeth to facilitate moulding and feeding, and a ring core is used to form the top part of this casting, thus making it with no lift at all in the cope.

Fig. 11 shows a pipe clamp which is air-machine moulded without any dry sand cores, sprigs or nails being used, and made from a cast aluminium plate. There are four castings per box.

Fig. 12 shows a hub for motor industry. In each box there are two castings and five cores. This is an example of the trouble taken to ascertain the correct amount of feeder required for each casting. The feeder is formed by two cores, both made from the same core box and placed together in the mould before ramming up. For its manufacture two aluminium patterns are mounted on steel plates.

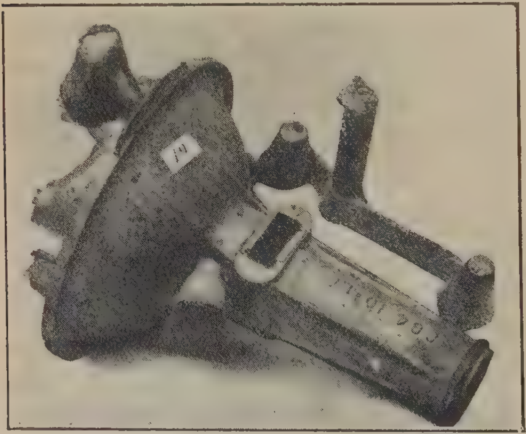


FIG. 19.—ONE-HALF BOX: 27.5 LB. PER CASTING.

Fig. 13 is an illustration of a clip showing an ideal type of top feeder for this class of work, being only about $\frac{1}{4}$ in. from the body of the feeder to the casting. It has to be removed whilst hot. There are two cores per casting. Four aluminium patterns mounted on a steel plate are used for its moulding.

Fig. 14 is the final example of snap-flask work, and the only one shown that has been chilled. This casting has to be cast stem upwards on account of there being no room for feeder on the reverse side. The top of the casting being the smaller will cool the quicker and leave a cavity at the root of the stem, therefore a specially-made chill is placed underneath the feeder. It will then knock off cold without fear of cracking the casting. Four castings are made per box from aluminium patterns on hardwood board.

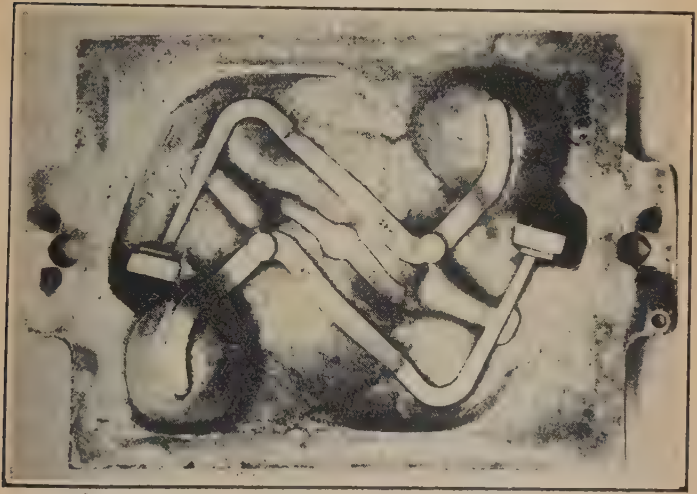


FIG. 20.—CAST ALUMINIUM PLATE.

Squeeze Jolting Jobs.

Fig. 15 is made from a wood pattern mounted on a steel plate in a steel moulding box on jolt-ram squeeze machine. There is one casting in a box carrying two cores. It shows the steps necessary for preventing some of the more fragile castings from cracking during cooling. As shown, two holes are inserted in the core for holding the two heavier sections together. These are removed after annealing; additionally, a fin is placed outside the two bosses for the same purpose, but these are removed before annealing.

Fig. 16 shows a casting made on an ordinary jar-ram machine which after a little trouble was made perfectly sound without any feeder at all, but the use of any other type or runner anywhere resulted in an unsound casting. Even if this type were moved from the thin section the casting would be unsound.

Sandslinger Castings.

These machines are the latest type the Leys Company have installed. They have five actually in work, making from 50 to 60 tons weekly. Fig. 17 shows a small steering box weighing about 7 lbs. For its moulding, four brass patterns are mounted on twin stripping machines. There are eighteen dry-sand cores per box, including four gummed in the cope. The size of the box used is 21 in. × 13 in. × 6 in. Four men and four boys make from six to eight tons per week. All cores for this class of work are machine made in oil-sand; in fact 75 per cent. of the cores used are of oil-sand. Note should be made of the fin on two castings to prevent pulls.

Fig. 18 shows a much plainer job containing one core per casting. This core, by the way, is made on a core-blowing machine similar to the one Mr. S. H. Russell described when dealing with his visit to America. The size of the box part used 17 in. × 17 in. × 4 in. The method of feeding is one to which resort is often made, that of carrying the metal from the feeder at the side through a pad into the neck of the hub. Three men and four boys will make, core, cast, and shake out seven to eight tons per week off this job. This is made on a drop-plate machine, wherewith the pattern and pattern plate drop and leave mould suspended on out-triggers.

Fig. 19 represents the type of casting suitable for the sandslinger. It weighs 27 lbs., and there are two castings per box, carrying 10 cores, including two gummed in the cope. For its making four complete grey-iron patterns are mounted on twin stripping machines, that is, two copes and two drags. The whole is mounted on a skid, towed behind the sandslinger. To staff this machine efficiently requires 15 men and five boys. A fair day's output from it ranges from 225 to 250 complete moulds, or 450 to 500 castings—in fact it has made 270 complete moulds in 8½ hours. There are actually seven men and five boys producing these moulds, the remaining eight men clamp, cast, shake out, prepare all sand and remove runners. The actual output of castings from the foundry floor at the time of writing is:—Castings, cast, 2,000; moulds made, 1,000.

General.

All moulding boxes for machine work whether of cast iron or light steel are used without fixed pins, but are fitted with double lugs all drilled to templates with different centres for various sizes of boxes, but all with a standard size of hole. The steel boxes have no handles, the lugs being used for that purpose. Cast-iron boxes have a lug cast on the corners carrying a hole, into which a bar is placed for handling. This facilitates passing up and down the rows for casting purposes. All pattern-plates for iron or steel boxes are fitted with standard pins and moulds are assembled with a pair of pins placed in the cope. One of the advantages of this method is that each pin goes through four holes, thus eliminating the risk of cross-jointed castings.

Seventy-five per cent. of the castings are poured through dry-sand cores in the form of strainers of different types. This is a great advantage where clean castings are essential.

London Branch.

STRIP CASTING.

By W. A. C. Newman.

The operations involved in strip casting are divided into two main groups: (1) Melting and (2) casting. In melting the principal points for consideration are: (*a*) Type of furnace and class of fuel, tilting, stationary or reverberatory, gas, coke, oil or electric; (*b*) size and shape of furnace hole; (*c*) capacity; (*d*) consumption of fuel; and (*e*) utilisation of waste heat.

By far the greatest proportion of the furnaces in this country are coke-fired and of the stationary type. There is, however, a good sprinkling of the tilting variety. The use of gas-firing is extending, and its economy, or otherwise, in relation to coke is one of the most debated questions among foundrymen. Gas furnaces are relatively infrequently used, though they are more cleanly and under better control than coke furnaces. The recovery of spilt metal is easier, and the quantity smaller; crucible life is probably shorter. The quality of gas is maintained at a steadier level than that of coke, and thus regularity of working is ensured. Gas firing is usually noisier owing to the need for compressors, and requires more skilful manipula-

TABLE I.—*Relative Efficiency of Gas and Coke Fired Furnaces.*

	Melt per furnace, 10 hrs.		Inc. in output.	Pouring Temp.	Cub. ft of gas per lb..
	Coke.	Gas.			
	Cwt.	Cwt.	Per cent.	Deg.C.	
Gold ..	5.2	9.8	88.5	1,150	3.12
Silver(1/-)	5.7	12.8	124.5	1,090	5.00
Bronze ..	5.2	13.4	157.7	1,165	6.50
Cupro-Nickel	3.6	9.4	161.1	1,300	9.8

tion to obtain the correct mixture of gas and air for the best heating efficiency. As regards consumption, Mr. Hocking, the late Superintendent at the Mint, gave figures to the Institute of Metals in 1917, comparing gas and coke firing over periods of five years when melting similar types of metals and alloys. They are as restated in Table I.

Electric Melting.

Electric furnaces for the melting of non-ferrous metals are still in their infancy, but for special purposes, in the case of iron and steel, they have been used widely. It may be said with confidence that the advent of the induction furnace, typified by the Ajax-Wyatt and the Ajax-Northrup furnaces, has opened up the possibilities in this field much more than hitherto. These furnaces are in strong competition even now with the older types, particularly where work is carried on through the 24 hours, and where high purity and freedom from contamination are desired. If power could be obtained more cheaply—down, say, to ¼d. or ⅛d. per unit—they would undoubtedly come into greater use. The newer, medium-frequency furnaces of the Ajax-Northrup type are particularly impressive, as their capacity is much greater than the earlier ones, which worked at higher frequency. Unfortunately their capital cost is at present rather high.

Capacity.

The most suitable capacity for the furnaces is directly related to the nature and size of the castings to be produced and the magnitude of the output expected. Where large ingots are being cast, the crucible charges may be larger than where the strip bars are narrow and small. In general, the crucible charge should not bear more than a definite, comparatively small relationship to the day's output; otherwise the failure of a furnace for any reason would mean the loss of too large a proportion of the output. In Mint practice we prefer to keep this ratio at about 4 to 5 per cent.

The utilisation of waste heat issuing from the flues and passing up the stack is a problem which has not hitherto had all the attention it deserves. In nearly all furnace installations some use could be made of the escaping heat units. The temperature of flue gases may range between 500 and 1,000 deg. C., and tends to be particularly high in the case of gas and oil furnaces. The following examples are given of the manner in which heat utilisation could be effected:— (1) Preheating the charge; (2) preheating the gas or air in the case of gas-fired furnaces; (3) raising steam direct, and (4) heating feed water for the boiler plant in some kind of economiser.

The economies which may be possible by each of these methods is worthy of consideration. The preheating of gas and/or air will probably be the most attractive. It is quite feasible with atmospheric burners working at low pressures by using a species of regenerative chamber. But with this system the time taken up in heating from cold is so great that 24 hours' working is a necessity, or at least some means of keeping the furnaces hot during the non-working hours. The preheating of either gas or air when under high pressure is more difficult. The speed of travel does not permit of taking up of much heat from the flue gases. In addition the problem of providing suitable heat-resisting pipes to convey the gases to the furnace through any flue chamber has retarded the application of such a method.

Recently the Mint has adopted an extended system of preheating the charge, and the results so far appear to justify the scheme. Average figures indicate that the gas consumption per cwt. has decreased by some 15 to 20 per cent. in the case of each alloy, and there has been a corresponding increase in output.

CASTING.

The factors which enter into the pouring operation may be summarised as follows:—(1) Temperature of melt and of moulds; (2) fluidity or viscosity; (3) rate of flow; (4) dimensions and design of moulds; and (5) condition of mould.

Temperature.

It is a commonly accepted principle that the pouring temperature should be as low as is compatible with getting the whole of the melt out of the crucible, forming solid castings, and allowing any occluded or trapped gases to escape from the mould. A figure usually named is 100 to 150 deg. C. above the freezing point of the material. But this cannot be taken as a hard and fast rule, for it is obvious that the body of the metal to be poured, the size of the mould, the melting point of the metal or alloy, and the solidification range are all points which bear on this important question. The pouring temperature can be lower when the bulk of metal is small and the mould takes the whole of the melt, than when the former is large and the moulds small. Further, it is possible to employ a smaller excess temperature in the case of a large charge than in the case of a small one, when pouring into similar moulds, as the radiation losses are relatively lower. In strip casting the conditions are usually those of a large body of molten metal being poured into comparatively small moulds, and it therefore becomes necessary to use higher pouring temperatures than when, say, large sand castings are to be run. In casting bronze containing 95 per cent. of copper, the pouring temperature for a 350- to 400-lb. melt is normally taken 200 deg C. above the freezing point. The time taken to pour such a charge into moulds $\frac{3}{8}$ in. by $3\frac{7}{8}$ in. in section and 24 in. long is about eight minutes. The drop in temperature is 50 to 70 deg. C. With alloys which have to be made hotter the temperature drop may reach 100 deg. C. This variation of temperature during pouring is liable to lead to irregular working qualities of the bars, but except under unusual conditions it is found with the majority of coinage alloys that a drop of 50 to 80 deg. C. is allowable without seriously impairing the mechanical properties. Two methods are available to reduce this temperature drop in the crucible: (1) By surrounding the crucible in the cradle with an insulating shell in order to reduce radiation losses, and (2) by reducing the size of the charge when pouring into the smallest bars, thus maintaining a fairly uniform total time of pouring.

Bars poured in this manner have clean edges and good surfaces; the pipe extends a fair way into the ingot, showing good contraction and indicating general solidity. Any tendency to overheating results in excessive splashing and, at the moment of casting, the liberation of large quantities of gas with which the melt has been supersaturated. This gas does not all leave the melt; part is entrapped and is the cause of some of the unsoundness. Increase in the rate of pouring accentuates these phenomena, while a decrease usually results in the diminution of the internal defects and a development of external ones. The slower pouring enables the ideal condition of solidification in successive layers to be attained much better than when the rate is greater. On the other hand, if pouring is too slow, the severely chilled metal crystallising from the mould surfaces obstructs the continuous flow of fluid material.

Messrs. Bamford and Ballard have recently come to the conclusion, that in ordinary foundry practice, using coke fires, it is impossible seriously to weaken the mechanical properties of a 70:30 brass casting by overheating or prolonged heating of the melt in the furnace. Cooling to within close range of the freezing point, however, certainly does so, and renders the casting porous. Their experiments also show that if the conditions of pouring are correct the nature of the atmosphere in which the metal is poured does not decrease the soundness of the casting. Thus they obtained solid ingots in each case when air, hydrogen, coal gas or sulphur dioxide was the surrounding medium. These results are rather contrary to the usual experience, and one would welcome confirmation in large scale operation.

Mould Temperatures.

Suitable mould temperatures have not been investigated as closely as pouring temperatures. In general it may be said that the initial temperature of the moulds should not be less than 100 to 150 deg. C. This is very much exceeded where several charges have to be poured into the same moulds. Cooling between melts is not always sufficiently speedy where output is a consideration, and in many instances quenching of the moulds is resorted to. Serious differences of opinion exist as to the advisability of such drastic treatment. Brearley, using large-sized moulds, obtained nearly 100 per cent. increase in life by quenching between heats. In strip casting the better method would appear to be to have such a supply of moulds that they can cool sufficiently by merely opening up to allow free circulation of air round them. Warming of moulds is essential in order to remove moisture from the surface and to temper the severe chilling as the metal enters; but here is a critical point beyond which warming merely exchanges one defect for another. Further it is necessary that the moulds be heated evenly in order to avoid the setting up of undue strains.

A knowledge of the temperature range of solidification is important in order that it may be known not only what is happening in the crucible but what is occurring in the mould itself. The pouring temperature must be, as we have seen, sufficiently above the freezing point to obtain a solid casting, but it is also important to know the possible changes taking place in the constitution and composition of an alloy whilst it is solidifying. Moreover, it is during this pasty stage that liquation effects chiefly occur, and a reshuffling, as it were, of the elementary constituents takes place.

Contraction on Cooling.

The linear contraction of an alloy is a function of chemical composition, of temperature, and nature and size of mould; relatively small amounts of impurities affect it. Theoretically the higher the pouring temperature the greater the contraction, as less metal can be held in a mould cavity at a higher temperature than at a lower temperature. Actually, pouring at an intermediate temperature gives greater contraction, as the evolution of gases at the higher temperatures causes a certain amount of artificial expansion. Generally speaking, the smaller the cross section the less the contraction for a given length; similarly if the cross section is maintained constant the greater the length the less the contraction. Contraction is greater in chill moulds than in sand moulds, assuming other conditions to be the same.

Fluidity.

This property is intimately connected with temperature, the higher the latter the less the viscosity. Adequate fluidity is necessary in order that the metal may fill the mould uniformly and that the chilling metal may unite with the solid material already in the mould. If perfect union does not occur unsound ingots result. It is obvious that there must be a critical value of the viscosity above which pouring should not take place. Japanese investigators have recently stated that in the case of most metals the viscosity attains a maximum value at about 100 deg. C. above the freezing point. This would be in reasonable agreement with general casting temperatures, but confirmation of this apparent regularity must be awaited.

Rate of Pouring.

The rate at which the metal enters the mould will affect the speed of solidification and is related to the pouring temperature. With metal sufficiently hot and flowing in a moderate stream, every opportunity is given to the occluded gases to leave the metal. With colder metal and a similar or slower rate of pouring, premature chilling results, and the ingots are uneven and rough. A primary consideration in the production of sound ingots is that the mould should be filled from the bottom upwards, and that solidification should follow the same general rule, so that each layer of solidifying material is in contact with still molten metal which can feed into the cavities caused by shrinkage, while at the same time offering the minimum of resistance to the liberated gases. In this manner the secondary filling commonly practised with large ingots in order to fill in the pipe is approximately copied. At the same time the bottom of the ingot is assured of being completely filled. A slower rate of pouring as the top of the mould is approached is found to help considerably.

Dimensions and Nature of Moulds.

The functions of the mould are to contain the metal and to conduct away the heat from the casting, so that the latter may solidify in a reasonable period. It must, at the same time be sufficiently strong to withstand normal handling.

Hematite iron is usually used in mould construction, although steel, malleable iron and nickel-chrome alloys have also been employed. The iron should be close-grained and capable of good machining, in order that the moulds may fit closely when placed on carriages. The quality of the iron is too frequently left to the discretion of the iron founder, and, indeed, there appears to be considerable difference of opinion as to a suitable composition. This is shown by the figures of Table II.

TABLE II.—*Composition of Ingot Moulds.*

	Lochner.	Redding.	Anderson.	Johnson.
C.C. ..	—	0.10	0.13	0.84
Graph. C.	—	3.57	2.98	2.76
Si. ..	up to 2.5	2.10	2.15	2.02
Mn. ..	>1.25	0.51	1.41	0.29
S. ..	} >0.1	0.66	0.086	0.07
P. ..		0.23	1.26	0.89

The greatest variations appear in the percentages of combined carbon, phosphorus and manganese. The phosphorus-silicon contents are usually regarded as the principal alternating factors. There is one school which demands high phosphorus in order to obtain good mould castings, while another school believe that the lower melting point of the phosphide eutectic tends to cause premature mould decay and they demand low phosphorus content.

Investigations in the Research Department at Woolwich have shown that smooth ingots of bronze, suitable for rolling, can be obtained from moulds of semi-steel CC, 0.79; Si, 1.43; Mn, 0.96; S, 0.071; P, 0.046. The moulds had a long life.

Prof. Carpenter and his collaborators have shown that growth in cast iron on repeated heating, a phenomenon well known, is directly caused by the oxidation of iron silicide, and is therefore related to the silicon content of the mould material. This growth may on occasions become excessive, say 10 per cent., when the silicon approaches 3.5 per cent. The presence of nitrogen or hydrogen increases the amount of growth, while phosphorus, sulphur and manganese tend to diminish it. An iron containing 3 per cent. C, 0.6 to 0.7 per cent Si, 0.5 per cent. Mn, is said not to grow at all, while one containing 2.5 per cent. C, 1.5 per cent. Mn, 0.5 per cent. Si, 0.1 per cent. S, and 0.1 per cent. P, actually contracts to the extent of 0.5 per cent. The maximum growth usually accurs at a point about $\frac{1}{3}$ of the way from the bottom of the ingot, where the heating is at a maximum, and where, incidentally, there is a tendency for the formation of an area of unsoundness.

For good rolling the edges of the ingot mould should be perpendicular to the face. Any chamfering to assist in releasing the bar from the mould induces bad rolling and cracked edges. The majority of alloys contract sufficiently to render such assistance unnecessary. For the production of good surfaces on the bars the faces of the moulds should be machined. This removes the hard casting skin, but the after-treatment of the moulds should provide a protection which compensates for this.

In some cases the newly-machined moulds are allowed to weather for some time and so become covered with rust. This is supposed to confer on the surface some life-prolonging property which is more imaginary than real. A more preferable way is to heat new moulds at such a temperature that they become blue on the surface. In this manner mould stresses are reduced, a hard oxide skin is formed, which is very resistant. Another method which is giving good results is one in use at Woolwich for which the author is indebted to Mr. Nesbit and Mr. Thorne. In this case the surfaces are consolidated by bombardment with small steel shot in a glorified sand-blasting machine. Moulds with aluminised surfaces are also being tried—so far with satisfactory results. New moulds invariably yield poor ingots on the first one or two occasions they are used, but the effect quickly dies down, particularly if they are given a wash of china clay slurry on the surface.

The thickness of the mould walls should not be less than $\frac{3}{4}$-in., and should increase with, but not in proportion to the size of the ingot. They should be of such a thickness that the heat from the casting is dissipated so quickly that at no time is their temperature nearer than, say 250 deg. C. to the melting point of the metal. Walls too thin warp readily and do not permit the maintenance of uniform temperatures. On the whole it is better to err in having the walls too thick rather than too light. It must also be remembered, in this connection, that casting into a chill mould requires a higher temperature than when casting into sand. Where the back and the lid of the moulds are not of the same thickness contraction cavities tend to be on the side nearer the thinner wall.

The size of the ingot itself is dependent on the nature of the work to be done upon it and the nature of the alloy. Thin ingots imply lower rolling costs, and are therefore preferred in many instances. Their use is a result of the balancing of economies in rolling costs and melting expenses to produce sound ingots. Given satisfactory conditions the thicker ingots yield sounder metal, and in many instances such ingots are afterwards rolled and then slit into appropriate widths. In their casting a rapid rate of flow can be maintained without disturbing the benefits arising from the increased thickness. On the other hand, casting into thin moulds—½-in. thick—demands a higher temperature and a fairly rapid flow in order to allow solidification to proceed normally. One advantage small ingots have is that the grain size is much more uniform, resulting in better mechanical properties.

A frequent occurrence in strip casting is a hollow on one or both broad faces, indicating transverse contraction on solidification. To counter this it would be necessary to go to the expense of giving slightly concave surfaces to the moulds, so that the metal when cast in them ultimately takes up its proper rectangular form. Moulds of this nature would naturally be more expensive.

The life of a mould depends on so many factors that it is impossible to give any reliable average figures. It depends principally on the nature of the mould, the casting temperature, general care in handling, cooling between melts, etc. The life of a grey-iron mould is shortened by too many coolings to ordinary temperature and is considerably lengthened if it is possible to keep it in continuous work, allowing only for normal cooling between melts.

One of the most serious factors which shortens mould life is the cracking which frequently occurs transversely across the back of the mould which is in contact with the front of the ingot. The cracking occurs much more often on this face than on the other, and most of all in the region of the supporting lugs. The first indication is the formation of a fine scaly deposit. This defect has been attributed in part to the impinging of hot metal on to the surfaces of inclined moulds and partly also to residual strains remain-unrelieved since the ingot mould was cast. One cure is to cast vertically into the moulds through a dozzle when there can be no point of concentrated heat. Cracking of the mould in its early stages does not cause the ingots to be so bad that they must be condemned, and it may be made less obvious by painting the mould surface with China clay. The deterioration once begun, however, is very rapid in going to completion, and the remaining life of the mould is comparatively short.

Mould Dressings.

The variety of mould dressings which are used in different works is indicative of the many attempts which have been made to obtain sound ingots with good surfaces. It appears that no general rule can be applied when casting ordinary commercial alloys. Indeed, the function of the dressing itself is involved and uncertain. It would seem reasonable to suppose that there would be some dressing, or dressings, most suitable for each metal, but there is certainly no uniformity in practice, and each foundryman prefers his own pet devices.

The most commonly used dressings are olive oil and lard oil, or mixtures of these, with plumbago; oil and resin; olive oil, turpentine and lard oil; tallow and oil; bone ash and water; thin fireclay; and a mixture of fireclay and sodium silicate applied in layers (this is not suitable for non-ferrous work).

A dressing which promised well was one of soot applied by holding the mould over burning turpentine or an acetylene flame. In the author's experience the results have been disappointing. While the surface was considerably improved the soundness deteriorated, and in addition the problem of applying an acetylene flame to a large number of strip moulds quickly and efficiently in large-scale work is no small one.

The flash point and the cracking point of a dressing should bear a rough relationship to the casting temperature of the metal to come in contact with it. Thus, for high-temperature casting a low flash-point oil, or one which cracks at a low temperature, is not satisfactory, owing, in the first place, to the wastage of oil in burning or by decomposition, when it should remain on the mould, and in the second place to the possible absorption of products of decomposition in the casting.

The part played by a mould dressing in the casting operation may be very complex. It may act as a protection to the mould, and there is no doubt this is largely the case particularly when using inorganic materials such as china clay. These are especially useful in filling in small cracks and other inequalities in the mould surface. Similar action may occur with the ordinary carbonaceous dressings, when the carbon left as a decomposition product acts as a filler. The burning of an organic material affords a reducing atmosphere in which the metal may be cast and allowed to solidify. This tends to prevent oxidation, but is liable to bring its own troubles in the absorption of the reducing gases themselves. For this reason, if for no other, the amount of lubricant should be limited to the minimum quantity actually required. In addition to acting as a deoxidiser, the reducing gas may possibly act mechanically in attaching itself to included matter or otherwise causing it to rise in the melt during its own passage.

Failure to clean and scrape moulds at definite intervals results in rough castings. In some instances the dressing brushes out cleanly, but in many cases, particularly with high zinc alloys, a day's work leaves the moulds coated with a hard, tenacious skin which is difficult to remove. A sample of such material from moulds used for brass assayed about 70 per cent. zinc oxide. The latter appeared to have formed a cement-like material with the oil. In our own practice at the Mint it has become essential thoroughly to scrape the moulds each morning, and in very bad cases to treat the moulds in hot caustic soda solution.

Unsoundness or Ingot Defects.

Defects in ingots may be divided conveniently into internal and external varieties. The former are mainly blowholes, contraction cavities, and inclusions, which on visual examination of a cross-section are seen to possess fairly definite characteristics:—(1) Clean spherical holes of varying size with bright surfaces. These have obviously been produced under reducing conditions, and very possibly enclosed some reducing gas. (2) Similar holes with black or dark interiors, due to oxides or sulphides. (3) Elongated cavities, more prevalent in the interior, and usually extended from the pipe. They usually occur with non-oxidised surfaces, as they are normally not produced in the presence of gas, but are due to contraction in the passage from liquid to solid. (4) Irregular masses of dirty material which may have contaminated the surrounding material by interchemical reaction; and (5) a general porosity consisting of very minute holes spread over the whole mass.

External defects may be classified as:—(1) Folds and incomplete castings due to chilling; (2) exposed gas holes, probably derived from the use of too much dressing; (3) flaking; and (4) surface inclusions, picked up from the crucible, charcoal covering or slag, or dissolved oxides.

Gas and contraction cavities roll out, forming hidden flaws. Where they occur there is always the hope that in the fillets or strips the sides have become united under pressure. This, in fact, is rarely the case, and only occurs at all in hot rolling at welding temperature, and if the surfaces are clean and free from oxides, sulphides, etc. Gas bubbles invariably reveal themselves in annealing as blisters or flakes due to expansion, whereas in the case of contraction cavities there is a greater tendency to lie low, there being no contained gas to lift the overlying metal. The possible relationship between blisters and flaking on the rolled fillets is a disputed point. It is fairly evident, however, that, in rolling, the skin covering blisters nearer the surface becomes very attenuated, and might conceivably break, causing flaking.

Unsoundness is not necessarily confined to the top or pipe portion of an ingot. It may be in evidence in two or three regions, particularly at a point some way from the bottom, probably coinciding with the spot at which the initial splashing quietens down and the crystals growing in from the sides obstruct the regular solidification of the metal. Signs of unsoundness may also be fairly commonly found towards the edges of the ingots but a little way in.

A considerable amount of attention has been given to the question of the effects of gases in metals and their removal, but the solubilities of gases in fluid metals is a field not yet covered very extensively. It must be agreed that each of the metals and alloys when molten can dissolve definite quantities of any of the gases, depending on the temperature and pressure, and in casting, therefore, each class of ingot presents its own peculiar problems, which have to be determined and solved, in most cases, purely empirically. For example, the solubility of oxygen in silver is very many times the solubility of the same gas in copper. When the two metals are alloyed the absorption power of the silver is reduced, and a state is eventually reached where we have a balanced reaction between silver and cuprous oxide on the one hand and copper and silver oxide on the other. Another example comes readily to one's mind in the greater solubility of gases in iron and steel than in non-ferrous metals. There is one marked difference, however, between the solubility of gases in molten metals and their solubility in ordinary liquids. In the majority of instances, in the former case, the solubility increases as the temperature rises, whereas in the latter case the solubility falls.

The following general relationships between gases and fluid metal may occur. (1) Total insolubility of the gas in the fluid metal. So long as the metal remains sufficiently liquid the bubbles will ascend and be liberated, but any gases still present in the metal when solidification has commenced, or when the viscosity has risen above a certain critical point, will be trapped. The rising gases may easily act as scavengers in the metal, and by their own buoyancy bring extraneous matter to the surface, thus playing a small but significant part in producing a sound casting. In addition, they reduce the partial pressure of any dissolved gas, causing it to be liberated, too. Mr. Archbutt has definitely used a similar method by purposely introducing a stream of nitrogen into molten aluminium alloys with this particular end in view.

(2) The gas is soluble only in the fluid metal. As the strip ingot cools, such gases are liberated to an increasing degree, and if cooling be sufficiently slow the metal will be completely free when solid. Sudden quenching or chilling results in the retention of the gas in a very dispersed form as tiny bubbles. Under normal casting conditions some of the gas would be given off, but undoubtedly some would be retained in the ordinary spherical cavities formed by the coalescence of the smaller bubbles.

(3) Gas partially soluble in the molten metal and also in the solid. Under these conditions the gas absorbed by a molten metal may be split into three portions:—(*a*) Part released in cooling; (*b*) part entrapped in the solidifying metal; and (*c*) part dissolved in the solid. The influence of these portions may be very diverse. That of released gases as a scavenger we have already noted. Entrapped gases form the blowholes whose evil effect is well known. Dissolved gases may have an effect which is not quite so clear. It is possible that, according to their solubility and their own particular properties they may confer varying mechanical and chemical properties on the metal or alloy which contains them.

(4) The gas combines chemically with the metal. This may result in the solution of the compound formed, *e.g.*, CuO in copper, its expulsion in the slag or its retention as an unwanted inclusion.

Air absorbed from the atmosphere or entangled in the stream and the furnace gases are the principal sources of the gases found in castings, and they may yield oxidising, reducing and neutral gases. The principal oxidising agent in this connection is oxygen itself, though carbon dioxide may on occasions act in this manner. The reducing gases are hydrogen and the saturated and unsaturated hydrocarbons, with possibly sulphur dioxide, while nitrogen, carbon dioxide, and sulphur dioxide are normally neutral. Of these, oxygen is the most chemically active in contact with metals, and the oxides thus formed, if not removed, are dissolved, or appear as inclusions. In certain instances the other gases react, as in the case of nitrogen in iron and magnesium when nitrides are formed.

There is some evidence that in many cases other gases are more soluble in metals than oxygen. Prof. Carpenter and Miss Elam have published results for gunmetal. They found that the gases do not readily escape from the metal, and observed the spurting of beads on cooling (Table III).

No marked difference however, between the gases was noticed which would account for the absence or presence of blowholes—a fact which conforms with other observations that apparently quite sound ingots contain considerable quantities of absorbed gas, most probably a highly dispersed phase. Dr. Hatfield has pointed out, for example, that the gases from a piece of blown steel are less in volume than, but similar in composition to, those from a sample of sound material, and incidentally suggests that use might be made of this fact by adding to steel certain proportions of various elements which would increase the holding power of steel for gases, and so possibly confer considerable improvement.

TABLE III.—*Composition of Gases in Gun Metal.*

	Pump started simultaneously with heating.	Apparatus allowed to cool before evacuation.	89 Per cent. Cu. 11 Per cent. Sn.	Rio Tinto B.S. Copper	
				Gas collected quickly.	Gas collected slowly.
SO_2 ..	15.6	—	53.4	70.9	61.2
CO_2 ..	3.4	5.8	5.1	19.6	34.9
CO ..	57.6	41.3	27.4	4.7	—
H_2 ..	7.6	41.0	—	—	—
Satd. hydrocarbs.	2.9	1.9	1.4	0.8	—
Unsat. hydrocarbs.	2.4	0.9	1.7	—	—
O_2 ..	1.1	1.2	1.4	1.2	1.1
N_2 ..	9.4	7.8	10.5	2.8	2.8
Vol. of gas 100 grms.	2.17	3.65	1.44	4.45	5.95

Guillemin and Delachanal have found that in sound brass castings 90 per cent. of the occluded gas is hydrogen, which had apparently no deleterious effect on the mechanical properties, and that chill cast bars contain less gas than bars cast in sand. The gas in this case was probably in a state of supersaturated solution. In the presence of P its solubility is reduced. In unsound castings the gases contained a considerable proportion of CO_2 and CO. Hathersall and Rhead have confirmed these facts. They have shown that molten copper treated with hydrogen will cast soundly under suitable conditions, while copper not so treated, but simply held under charcoal, does not, under the same conditions, give good castings. Lobley and Japson, on the other hand, had found that H_2 is absorbed in Cu at all temperatures up to 2,200 deg. C., and is ejected on solidification, forming blowholes.

The causes for the presence of oxygen, as such, or as oxides in alloys are, principally, prolonged heating, melting without a cover, exposure to an oxidising flame, the introduction of too much scrap which, with its greatly developed surface, offers greater opportunities for oxidation, and in the case of alloys containing copper, the dissolved cuprous oxide. It is common practice to deoxidise a metal by adding a reducing medium, which will combine with the oxygen and pass off as vapour, into the slag or into harmless solution in the metal. To de-reduce a metal an oxidising agent must be added. Whereas, however, in the former instance the products of deoxidation are rendered innocuous, in the latter we are invariably left still with a gas and all its attendant evils, necessitating careful measures to prevent its retention in a harmful state in the metal. Thus hydrogen will form steam and carbon monoxide carbon dioxide.

The oxygen in copper is present as cuprous oxide, which on solidification of the metal becomes concentrated in the part solidifying last and finally forms a eutectic, which surrounds the crystals as a brittle membrane. Thus 0.5 per cent. of O_2 as Cu_2O does not affect the ductility of copper, but 0.10 per cent. reduces it. In bronze, brittleness due to oxygen is less to be feared than in copper owing to the influence of the zinc which reduces the CuO to Cu and forms ZnO—a less harmful constituent.

To a certain very limited extent, oxygen may be beneficial in such materials as the copper alloys by oxidising the impurities which are less harmful as oxides than as the pure elements, and thus assisting their removal.

Non-ferrous alloys may be divided into two classes for deoxidation purposes. (1) Alloys which undergo autodeoxidation when molten, *e.g.*, Al, Si and Mn bronzes; and (2) alloys in which it is difficult to separate the oxide of one or other of the constituents. Add deoxidiser (1) to prevent undue loss of reactive constituent and (2) to reduce oxides formed during melting.

The usual deoxidisers are well known, and need not be recapitulated. Their efficacy is in relation to their several heats of oxidation, or, in other words, the heats of formation of their oxides. The higher this quantity, indicating greater affinity for oxygen, the more virile is the deoxidising power of the element. Generally speaking each deoxidiser will act as such to the oxides of the metals below it in the series, which is a useful guide when determining the particular reagent to be used.

The efficacy of an ordinary graphite stirring rod as a deoxidising medium is not fully realised.

The addition of deoxidisers while reducing the amount of included oxides at the same time increases the fluidity which enhances the chances of obtaining a sounder casting.

Inclusions.

Inclusions in strip ingots may be equally as detrimental as gases and blowholes. Charcoal, chips from the crucible, oxides and dross, slag and carbon from the cracking of an unsatisfactory mould dressing may all appear in the ingot. Both subcutaneous and deep-seated foreign matter reduces the strength, and the former may develop into flakes on rolling. Evidences of inclusions are frequently seen in the laminations in rolled strip due to the non-adherence of adjacent metal. These laminations can usually be lifted with any sharp point, and in rolling or spinning are very deleterious.

The various common oxides which may occur as inclusion are those of copper, aluminium, zinc, magnesium and tin. Cuprous oxide dissolves to a considerable extent in copper, but in alloys the conditions are different. For instance, in brass, since zinc reduces cuprous oxide, but copper does not reduce zinc oxide, the latter must be the principal inclusion, if any. Alumina forms a continuous film on the surface of the molten material even when aluminium is present in only small quantities. The oxide is difficult to eliminate. The skin formed on the surface, however, prevents the oxidation of the other oxidisable metals present. The ease with which alumina is formed is the primary cause of the difficulties in casting aluminium bronze and similar alloys by preventing the agglomeration of the molten globules.

Zinc and magnesium oxides are friable and easily become entangled in the melt. Tin oxide forms hard and brittle, well developed crystals, and imparts these properties to the alloys.

Manganese, silicon and phosphorus form oxides which volatilise or pass into the slag.

The external defects are more difficult to classify than the internal ones, for their differences are not so marked. Folds or spills are due to incomplete union of splashes with the main body of metal during pouring, owing to excessive chilling or the intervention of some foreign matter. Pits, which may be circular or elongated, are due principally to mould defects or to inclusions which have attempted to rise up the mould side but have been trapped.

Of the two forms of defects, internal and external, the effect of the latter can be more easily removed, simply by planing the surface. From this point of view, therefore, it is preferable to aim at greater internal soundness than perfection of surface, though from an economic point of view the better the surface the less costly are the subsequent operations. With small strip ingots, such as are used in coinage work and are produced in large numbers, planing is impracticable, and reliance must be placed on the efficiency of casting methods. For superfine work planing is eminently desirable. It becomes then a question of weighing the economic considerations—the cost of additional operations, such as planing—and the purchase of comparatively costly plant which is necessary to ensure the best conditions for ingot production at the outset, against the cost of rejected work due to the defects which have been enumerated.

Irregularities of Compcsition.

In addition to what may be called the casting defects of an alloy there are frequently irregularities in composition, which may be modified or improved by alterations in the casting conditions. Some, however, remain in the ingot.

Improper mixing, whereby uneven distribution of the constituents may result. This is particularly noticeable where there is an insoluble constituent (*e.g.*, lead in bronze), or where there is a marked difference in density between the original components, or between the phases which may be produced. An instance of the latter is the concentration in the upper layers of an ingot of white metal of the cubes of the tin-antimony compound. Intensive chilling causes better distribution, as the solidification is so rapid that no separation has chance to occur.

Segregation and Liquidation.

The segregation of impurities in the pipe and the central unsound portions of ingots, particularly steel ingots, has long been known, and it has recently been observed that blowholes are often centres of excessive segregation. The differences occurring between the inner and outer portions of gold and silver bullion and of ferrous and non-ferrous alloys in general have also been repeatedly recorded. These differences vary from those which might be expected from a consideration of the equilibrium diagram, and the term inverse segregation has come into use to describe such phenomena. Prof. Benedicks has investigated the carbon distribution in steel ingots, and Dr. Smith and others have similarly explored the vagaries of non-ferrous materials, notably the precious metal alloys. These properties appear to be inherent in each type of alloy, and have to be borne in mind in connection with the particular uses to which the strips are to be put.

DISCUSSION.

The discussion was opened by the Chairman (Mr. A. H. Mundey), who said he had been particularly interested in Mr. Newman's address and was specially interested in the question of the oil dressing. He knew that one particular section insisted on lard, another on whale oil, and some on seal oil as the basis of the dressing. He could never quite understand why, because he felt that the temperature at which the metal is poured is undoubtedly above the flash point or the cracking point of any of these oils.

The Durville Process.

Mr. Wesley Lambert said that the casting of metal into iron moulds, as described by the author of the Paper, scarcely came within the practice of the British foundryman; this class of work was done by metal casters. During the war quite a number of firms were asked to cast strip ingots of copper-nickel. All those who have had experience of that metal know what a job it is to cast successfully such ingots. The casting of strip ingot is not an exact science, if it were, success would be more general. The casting of successful strip ingot is an art, and amongst those craftsmen engaged in casting strip ingot, some are more expert than others. It is quite true that to the casual observer no particular pains seem to be taken, and that the metal is simply poured into the moulds, and yet when one examines the ingots produced one had to admit that they had a very good appearance, and one began to wonder whether the secret was in the particular mould-dressing used.

In the Durville process the metal flowed into the moulds in a very gentle manner, a method which appealed to him because he could not perceive how it was possible to pour metal rapidly into an almost vertical mould, sometimes of considerable length, and to ensure uniform success with the absence of "shotting" and splashing; both of which happenings produced defective ingots. He favoured the Durville process, although personally he had not had an opportunity of trying it out in practice. Some years ago he had rigged up a somewhat crude piece of plant resembling the Durville machine, and had met with a certain amount of success. He did not gather whether the Durville method of casting had actually been put into operation at the Royal Mint. It seemed to be a very promising process, and he thought it might have a big future.

He was particularly interested in the question of segregation in ingot metal, of which mention had been made. Some metals, naturally, were more prone to segregation troubles than others. The most successful ingot, so far as freedom from segregation was concerned, was the one made under conditions conforming most closely to the known requirements of science. In other words, if one succeeded in getting a good cast in metals which were liable to segregation troubles, then wittingly or unwittingly, the best use of scientific principles had been employed.

Gases in Metals.

Professor Turner said that some of them would remember the Paper by Mr. Cartland, who carried out experiments on the gases in brass. He extracted them and found that the quantity of gases was extremely small, in the order of something from about 5 per cent. of the volume of metal. Then they had had the gases extracted from steel, by Mr. W. Austin, and they found that they were of the order of five times the volume of the metal, so there was a very great difference. Then again Bamford and Ballard, working under his direction, carried out those experiments to which the lecturer had referred, finding that with brass it did not matter very much what the temperature or the atmosphere was; whether it was hydrogen, or carbon dioxide, or air, the results were alike and the quantity of gas absorbed by the brass was very small. Those who had experimented with other metals would have come to other conclusions, and the question was: How were they to reconcile the discrepancies? It might be illustrated by the gas in water. That was a typical liquid for the absorption of gas; no matter what the temperature was, it was found in nature to be practically saturated by gas under existing conditions. Freeze that water and it would give off gas, and if it were frozen quickly it would make opaque ice. On the contrary, if they raised the temperature of the water they would see bubbles of gas coming off. There was evidently a point of maximum solubility. With water when the temperature rose, they had an increased vapour pressure. It was a question of the partial pressure of the gas, as if they had an indefinite quantity of water vapour, that washed out the gas, and so the gas was given off. Now they had precisely the same conditions in brass. The experiments by Cartland and by Bamford and Ballard had to do with brass and not with metal which did not contain any volatile constituent. When they melted brass zinc vapour was given off, and for all practical purposes an indefinite quantity of zinc vapour was given off. That consequently washed out the other gases, and the result was that the quantity of gas which remained absorbed in the brass was extremely small. In copper, however, the quantity of gas dissolved increases as the temperature rises, or if the pressure increases the quantity of gas dissolved in the metal increases, and if they wanted sound castings, in that case they would have to take special precautions. One was the method adopted in the National Physical Laboratory, that of melting the metal and heating it above its melting point, allowing it to cool so as to give up the gases, cooling it off for a short time and then heating it up again. They were dependent first upon the character of the metal itself and the solubility of the gas in that metal and secondly on the volatility of the metal. When melting metals or alloys, there would be practically no effect from the atmosphere if a volatile constituent was present, because of the vapour pressure of the volatile constituent.

Influence of Casting Conditions on Subsequent Rolling.

Dr. W. Rosenhain said that Mr. Newman's account of the strip casting process for coinage was interesting, and must have been even more interesting to those who were unacquainted with it. Yet it was interesting to him because it showed how thoroughly the various aspects of this strip casting problem had been considered. Mr. Wesley Lambert said that if one went into an ordinary foundry and saw strip casting in progress one would think that there was not very much in it. But when one studied the returns from those strip castings one would realise that there was a great deal in it if it were to be done as it ought to be done. In other ways the ordinary brass strip presented special problems. It had to be produced in longer lengths than the twenty-four inch casting used at the Mint, and in casting a long strip there was great difficulty in controlling the flow of the metal into the mould and maintaining a good, undamaged surface. To show the great effect of the method of casting, he wished to refer to the picture of the old casting machine which Mr. Newman had taken from a Report published in 1921. The object of that machine was to provide a specific path for the inflowing metal so that there should be no splashing and the mould would be steadily filled. Using that machine and varying the conditions of casting, it was possible to produce slabs of widely varying quality according to the temperature of the mould and rate of pouring, and it had been found that the behaviour of the slabs on subsequent rolling was also extraordinarily different. It was, in fact, possible to predict how those various slabs would behave. On one occasion a demonstration was given to a number of visitors in which a certain number of slabs were taken out of the same furnace, and it was predicted that certain ones which had been cast in a particular way would roll perfectly and that others would split, and every slab behaved as predicted, which showed that the behaviour of a cast body when rolled can be largely influenced by the mode of solidification. In the case he mentioned it was a matter of the size of the chill-crystals growing out from the sides of the mould and whether these crystals met in the middle or not.

There was just one point where some of the considerations Mr. Newman mentioned were not quite everything to be considered. He referred to the thickness of the mould walls. The heat capacity of the mould in relation to the heat capacity of the metal was of vital importance in determining the mode of solidification. Satisfactory results with certain alloys were only obtained if the weight of the mould was about three times the weight of the casting. That ratio might not apply to all metals, but in the particular case he mentioned it was an excellent guide which they found applicable to castings ranging from a tiny die casting of a quarter of an inch thick up to a three-inch ingot. Then came the difficulty of the material of the mould. Cast iron was used in most cases, and it had one very serious disadvantage, that was its porosity. Whatever dressing was used, if the iron was of an open grain, the dressing would not overcome it.

The Mint problem was a special one, because machining of the surfaces was not feasible, partly because of the loss of metal in the process. Machining should not be necessary, because it was possible to cast bars with a good surface. The most serious difficulties were the uniformity of composition, and the perfection of the surface. The countervailing advantages were that the alloy used could be freed from gases easily and the use of a comparatively small size of mould. When it came to the study of larger and longer ingots the problem was a very different one, and when Mr. Newman had an opportunity of casting metals of a more difficult kind into long strip moulds he would find himself faced with a large number of new problems. He (Dr. Rosenhain) was convinced, from the way in which Mr. Newman had dealt with his subject that night, that those difficulties would also be overcome in an equally efficient manner.

Casting Silver Ingots.

Mr. G. C. Pierce said he had been recently dealing with the casting of precious metals in the shape of standard silver. His difficulty was to get it into ingot form yet suitable to be drawn into very fine wire. Five hundred ounces of pure silver made something like five miles of wire, or, in other words, it had to be drawn down to two-thousandths of an inch diameter. He did not know which method of working required the more perfect condition of metal, that of drawing or rolling, but it did seem to him to be necessary for the metal to be as near perfect as possible for it to be drawn down to such a diameter. Some of his colleagues of the Institute of Foundrymen would remember that he worried them one night to give him a suitable dressing for a cast-iron mould, which he wanted to use for silver. He tried every kind of oil, and eventually he used castor oil. That might surprise some, but actually it proved highly successful. He had also made a couple of cupro-nickel ingots in the same mould with the same dressing. The lecture to him was also interesting because much had been said relative to methods of pouring.

The cast-iron ingot mould he was using was carrying something like 2.5 per cent. of silicon associated with fairly high phosphorus. He always cast absolutely vertically, and as the work was 3 ft. long and 1¾ in. diameter, he was a little surprised to think that he had been successful when he had heard so much about the only successful method of pouring. It was only in his first two or three attempts to get those bars did he have any trouble, and he put that down mainly to the dressing of the mould and the method of melting the metal. He found it necessary carefully to protect the metal and also to take a good amount of care in the application of the dressing of the mould. He was, however, perfectly successful so far as he had gone with the bars he made, and apparently he had overcome the matter fairly well without any of the intensely scientific applications such as were employed at the Mint.

Quiet or Still Casting Conditions.

Mr. F. Kayser (Sheffield) said that mention had been made about the disturbance of the mould while the metal was solidifying, which was detrimental. On what did Mr. Newman base that statement, because he distinctly remembered on several occasions having seen reference to moulds being agitated? Then there was the statement about the pouring down the side of the mould. They must remember that they would come to a point when that system was quite impossible, that was when the metal had a high melting point. Steel, for instance, must not be poured down the side of the mould, otherwise it would be frozen. He pointed out that it was quite easy to pour down a mould, only an inch wide, without touching the side if a tundish was used. He would like to classify strips into two classes, those required to be hot rolled and those required to be cold rolled.

Furnace Efficiency.

Mr. H. C. Dews pointed out that he had had to deal with the problem of casting in chills bars 9 ft. long, varying in diameter from $\frac{1}{2}$ to $1\frac{3}{4}$ in. That was quite a difficult proposition, and he found the only way was to cast with the mould perfectly vertical. The metal must not run down the sides of the mould, and, in view of that, he was rather surprised to find that the Durville principle and other similar processes had had such success. With regard to the material for moulds for chill casting, here again they were up against the same sort of difficulty they met with in almost every scientific discussion, and that was that they did not know anything about cast iron. If they studied the literature on the subject they would find an enormous diversity of opinion. There were two schools, one which favoured high phosphorus and the other which favoured low phosphorus. Personally, he found in those experiments that the mould which gave the best results was the one made approximately of the same composition as the one Mr. Newman mentioned as used by the authorities at Woolwich. He favoured a fairly low silicon, high manganese and phosphorus about 0.2 per cent. Those moulds were giving very satisfactory service.

As regards the dressing, he was in agreement with what had been said. They could never go into two foundries doing the same work and find that they were using the same mould dressing. There seemed to be a need for a very close scientific investigation into the requirements for a good dressing. He did not mean that the flash point or that the commonly accepted properties of the oil had much to do with the particular problem. Mr. Newman's notes on melting were particularly interesting. The pre-heating was somewhat novel, although similar schemes had been attempted in one or two cases, but it was the first time he had heard of that particular system mentioned by Mr. Newman, and it semed to be a valuable hint. Then he wished to mention that the thermal efficiency of a pit-type coke-fired crucible furnace was something like 3 per cent., which made one wonder where all the heat went. He put a pyrometer in the flue of an ordinary coke-fired bronze hole, and the temperature was between 400 and 300 deg. C., so that in that case he was rather wondering whether that system of pre-heating was going to raise the thermal efficiency very much.

Apparently Similar Casting Conditions Differentiated.

MR. BAILEY said mention had been made of the effect of the stream on the walls of moulds, and doubts had been expressed about the Durville process on those grounds. He pointed out, however, the disadvantage of a small stream of metal impinging steadily on the walls of the furnace, and the advantage of the Durville process in which the stream flows in extremely gently. There was no continual impinging on one spot of the wall of a stream of metal.

Author's Reply.

MR. NEWMAN, in his reply, said with regard to the mould disturbance, that they at the Mint had found that the shifting of the mould carriage as each mould was filled had materially influenced the physical properties of the bars of certain alloys cast in these moulds. It was a fact that vibration of the mould had been tried as a positive measure and found to be successful, but, no doubt, particular conditions were required for particular alloys. In regard to the pouring down the sides, of course, in strip casting they did try to pour centrally into the moulds, and they did adopt the method which had been suggested that night by Mr. Kayser of using a crucible with a slit in the bottom in order to direct the stream through the centre of the mould. The strip casting he had mentioned was the method they used for strips to be rolled cold. The closing up of cavities could only occur if the strips of ingots were made hot before rolling. Mr. Dews referred to the temperature of the gases and in an ordinary coke fire flue the temperature would be about the temperature he mentioned, about three hundred or four hundred degrees. In one particularly bad set of furnaces they found that the temperature went up considerably, and that was the experience which led them to try the pre-heating methods in order to endeavour to use up some of the heat which otherwise would be lost.

Vote of Thanks.

Mr. Faulkner said the present meeting was always looked forward to with particular pleasure by the members of the Institute of British Foundrymen. This was the sixth year they had had the joint gathering, and each year it had become larger and more interesting. The lecture had been one which had a definite appeal to foundrymen, and even the most practical man could not complain that the lecturer had been speaking above his head. If he might digress, he wished to say how much he appreciated Dr. Rosenhain's remarks on the ingot moulds, and he wished to draw their attention to the thin plate at the back of the ordinary kitchen fire grate which was heated and allowed to cool three hundred and sixty-five days of the year, and did not suffer from the evil effect of growth. It seemed that the influence of mass was more important than the oxidation of the silicon content. On behalf of the Institute of Metals and the Institute of British Foundrymen he proposed that a hearty vote of thanks be accorded the lecturer.

The Chairman stated that it was his duty, as chairman of the Local Section of the Institute of Metals, to second the vote of thanks, which he did with great pleasure. He knew that Mr. Newman had the gift of putting before the practical man and before the scientific man matters which were of so great an interest in an intelligible manner so that they were instructive to both sides of the house.

Many Women Metallurgists.

He also wished to mention that they were very proud indeed at having heard of Dr. Elam, who was a member of the Institute of Metals, and a friend of many of them, who had been promoted to a big job in South Africa. They were very proud of it, indeed, but he did wish to protest against the statements in the daily Press that she was the only woman metallurgist. They had that distinguished woman, Dr. Marie Gayler, who had done wonderful work under Dr. Rosenhain. They had others; there was Mrs. Shaw Scott, Miss Kathleen Bingham, Mrs. Hanson, Miss Grace

Ford, and several others. He mentioned those named without taking the slightest credit from Miss Elam.

Mr. Newman was accorded a hearty vote of thanks, and the meeting then terminated.

West Riding of Yorkshire Branch.

THE SELECTION AND USE OF REFRACTORIES FOR IRON FOUNDRIES.

By C. Presswood, B.A. (Member).

The ideal refractory material would be as little affected by the operation of melting and casting iron and steel as is the familiar iron spoon by the melting of lead or white metal. Commercial refractories, however, are far from ideal, and are the subject of endless criticism from those who use them, criticism which is to some extent justifiable, but which should always be tempered by the reflection that so far as our knowledge goes at present there does not exist a material which is as insensitive to molten iron as is the iron spoon to molten lead.

A justifiable complaint may be made when manufacturers of refractory materials fail to make the best use of the materials which nature places at their disposal, a condition which generally arises from ignorance or carelessness. Whilst it is not intended to make this Paper an apology for the shortcomings of suppliers, it is assumed at the outset that needless trouble and complaint arises from faulty selection and subsequent misuse of refractory materials.

In discussing selection and use, it is well to bear in mind one or two premises, (a) that it is impossible to make wise selection or careful use without reference to conditions under which the refractory materials will be used, (b) that selection and use should always be based on a knowledge of the properties of the materials in question, and (c) that first cost is no criterion of the ultimate value. It is bad policy always to buy the cheapest material, and it is folly to purchase highly expensive materials if their "life" in use does not warrant the expense. Some purchasers err in the former direction, a few in the latter. In considering costs, too, it is important to include the cost of labour in making replacements, the incalculable lost profits and disorganisation whilst repairs and replacements are effected. So that, though the manufacturer may charge for a special refractory six times what he would charge for the ordinary type, the former need not give six times the life in order to justify its cost. Twice the life may in some cases be acceptable.

The true cost of refractory materials is only measured by their cost per ton of metal produced over a long period, and it is this cost which must be made the basis of wise selection.

It is sometimes worth while to increase the cost of refractories per ton of metal for the sake of regularity in material and delivery, and the foregoing remarks need modifying and amplifying when the refractory has a direct influence on the quality of the finished product. Moulding sands will probably be the case uppermost in your minds. In a case like this it is not generally wise to consider the materials merely on a basis of cost per ton of finished castings, since the better, and probably more expensive, moulding sand will produce a more attractive and reliable casting which sells more readily in the face of competition —a fact which can hardly be valued, but which must be considered. There should be more figures of true cost of refractory materials available as they would greatly assist manufacturers in making improvements and in marketing new materials.

Desirable Properties.

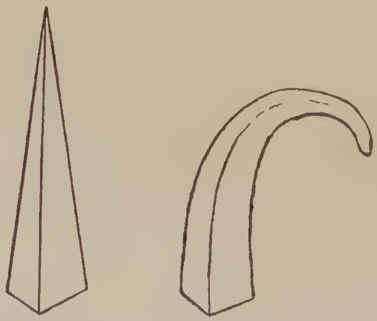
What are the conditions which a refractory material may be called upon to withstand? Briefly summarised, they are:—(1) Intense heat; (2) chemical action of slags, ash, gases, etc., commonly called "fluxes." The damaging effect of these is due to the fact that they combine with the refractory material to form compounds which are very easily melted, and the thin slags thus formed easily penetrate far into the refractory, particularly if this be porous; (3) physical and mechanical conditions such as heavy loads, abrasion, "flow" and "wash" of thin and viscous slags and metal; (4) changes of temperature, which are sometimes very sudden; (5) oxidising and reducing atmospheres, and, lastly, one might add, (6) rough handling before use.

All these affect refractories in iron foundries and generally two or three act simultaneously.

Selection and Use.

Selection, as well as use, must be based on the criteria by which refractory materials are judged, and these may here be briefly summarised and explained.

They are:—(1) Refractoriness; (2) thermal expansion—reversible and irreversible; (3) degree of firing to which burnt refractories have been subjected in manufacture; (4) spalling propensities which are estimated by (a) porosity, (b) texture, and (c) density—apparent and true, from which porosity may be deduced; (5) crushing strength, and (6) analysis and mineralogical constitution, both of which are important, since it is clear that two materials showing approximately the same chemical analysis may have widely different properties in consequence of different mineralogical constitution.



Test Cones.

Fig. 1.
Before Firing.

Fig. 2.
After Firing.

The term "refractoriness" is difficult of definition, but is generally taken as the temperature at which a specimen shaped particularly as a cone (Fig. 1), bends to a certain extent (Fig. 2). The method of temperature measurement should be fixed, and it is well recognised that, amongst other factors, rate of heating has great influence on the result. Moreover, the conditions in the test furnace are not comparable with those in industrial furnaces, and consequently a figure indicating "refractoriness" must be taken with a certain amount of reserve.

It is, however, quite certain that "refractoriness" does not mean "melting point." In fact, refractory materials, being rarely pure substances, but very complex mixtures, have no definite melting point in the sense that pure ice has. Nor is the refractoriness the same thing as "softening point," since the test cone may be soft long before it bends. Viscosity of the soft refractory is important here as well as texture, and it is clear that of two test cones of different materials, placed side by side in the furnace, one may be soft before the other, but may not be the first to collapse. In other words, the material which softens first may prove in the test to have the higher refractoriness.

Since refractory materials generally soften far below the temperature indicating their refractoriness in standard test, this temperature must be well above that at which they are to be used. The temperature difference between first signs of softening and final bending of the cone may be as much as 300 deg. C.

Fortunately there now is at the disposal of foundrymen a test which, though open to some criticism and imposing conditions on the test-piece by no means identical with actual furnace conditions, does more nearly approximate to a practical test. The test is known as the "under-load" test, and gives a figure far more reliable in estimating the probable value of the material in service.

In this test the material to be tested is carefully cut and ground to shape of a prism $3\frac{1}{2}$ in. by 2 in. by 2 in. It is then heated in a specially-designed furnace, generally electric, and so designed that during the whole range of heating a constant load is applied to the specimen. The prism, of course, changes in volume, but the weight system is so devised that expansion and contraction do not alter the load. The material ultimately becomes so soft as to be incapable of supporting the load and it collapses. The temperature is carefully measured by pyrometers at regular intervals throughout the test, and as far as possible a standard rate of heating is maintained. The temperature at which collapse takes place is known as the " under-load refractoriness," and may be expressed as degrees Centigrade or Fahrenheit, or as Seger cone equivalent.

A further refinement consists of a recording needle and chart, the needle being fixed to an arm which transmits the expansion and contraction movements of the specimen to the needle. An expansion curve results, from which the temperature of collapse may readily be deduced, as shown in Fig. 3.

In comparing figures for different materials due attention must be paid to conditions such as load, rate of heating, and so forth. Thus, in America, the under-load test specifies 25 lbs. per sq. in. In this country the load adopted is 50 lbs. per sq. in., a figure which covers all loads carried by refractories in industrial furnaces. Unfortunately there is as yet no universally accepted specification of test conditions, so that the difference between figures for two different samples may not be a true indication of their relative value.

Effect of Atmosphere upon Refractoriness.

Generally speaking, oxidising atmospheres are best for refractories, especially if they contain ferric oxide. The laboratory tests already mentioned clearly indicate that refractoriness of materials containing ferric oxide is considerably lowered by a reducing atmosphere, *i.e.*, an atmosphere of hydrogen or carbon monoxide. The presence of these gases indicates that there is an insufficiency of air (or, more scientifically, oxygen) for complete combustion. The effect on refractoriness can be interpreted simply as follows:—

Ferric oxide in the refractory is reduced to ferrous oxide, a form in which it readily combines with the other fluxes and silica, to form complex silicates whose fusion point is very low, much lower than the corresponding compounds formed by ferric oxide. There are figures available which give the reduction in refractoriness caused by various percentages of ferric oxide, but these may here be passed over with the deduction that if refractories are to be used in a reducing atmosphere they should not contain more than 1 per cent. Fe_2O_3.

Volume Changes with Temperature.

These are very important, and whilst the actual figures of coefficient of expansion are of more interest to furnace designers and to users of furnaces, such as the open hearth, than to iron foundrymen, the relative values and general differences between various classes of refractory materials should be known. A point, important, and not always fully appreciated, arises here.

Whilst, in comparison with metals, refractories may be said to have little or no expansion with heat, yet they do all expand and contract as temperature rises and falls, just as does a bar of iron. Whereas the expansion of silica bricks is large and important, that of sillimanite bricks is infinitely small, and can almost be neglected. This expansion and contraction is called the "reversible thermal expansion," reversible since the expansion on heating is, or should be, equal to the contraction on cooling back to the original temperature. The "reversible thermal expansion" is important and can be accurately measured in the test furnace.

But it is commonly found that after a specimen has been heated and allowed to cool, no matter how often, it never recovers its original size and it is "permanently" smaller or larger. This "permanent" change in volume is called the "after-expansion" or "after-contraction" and is of great importance. It is due to the fact that in heating all refractory materials, chemical and physical changes take place. These are often very slow and heating has to be stopped before they are complete. They are "arrested" reactions, and subsequent heating and cooling tends to carry them further. Now the nature and extent of these reactions with their attendant volume changes varies widely from one class of brick to another. By careful manufacture it is possible almost to eliminate the "after-expansion" and "after-contraction" (up to temperatures of 1,400 to 1,500 deg. C.) and the "after-expansion" test is therefore valuable as a guide to the care with which burnt refractory materials have been manufactured. This test is usually standardised as heating the specimens up to 1,410 deg. C. at a rate of 50 deg. per 5 min., and holding at that temperature for two or four hours. In such a test, a badly-made firebrick would contract and a silica brick expand.

Whilst this feature applies only to burnt shapes such as cupola bricks and blocks, and not to raw mixtures, it should be emphasised that the value of many pastes, cements, ground ganisters, compositions, etc., is dependent upon the amount of burnt material which they contain. This material, called "grog" by the firebrick manufacturer, has been shrunk or thoroughly expanded before incorporation in the mixture. It lessens the shrinkage or expansion of the composition in question.

Since linings expand and contract under load when in use the value of an underload expansion curve is apparent.

Selection of Burnt Raw Materials.

In the selection of burnt refractory materials, the extent to which these have been fired in manufacture is very important and is largely indicated by the tests just described. Some of the constituents of a refractory which has been overburnt may have melted, and the material, on cooling, contains a fair proportion of "glass." It is, in consequence, often liable to spall if used in conditions which encourage this feature, namely, alternating temperatures.

Spalling.

Spalling is a common feature in materials which have high expansion or contraction, whether reversible or permanent, but the tendency to spall is greatly reduced if the material can expand or contract freely. Generally this is not the case when bricks are built into furnace walls even if "expansion joints" are provided. The texture of a brick is important in this con-

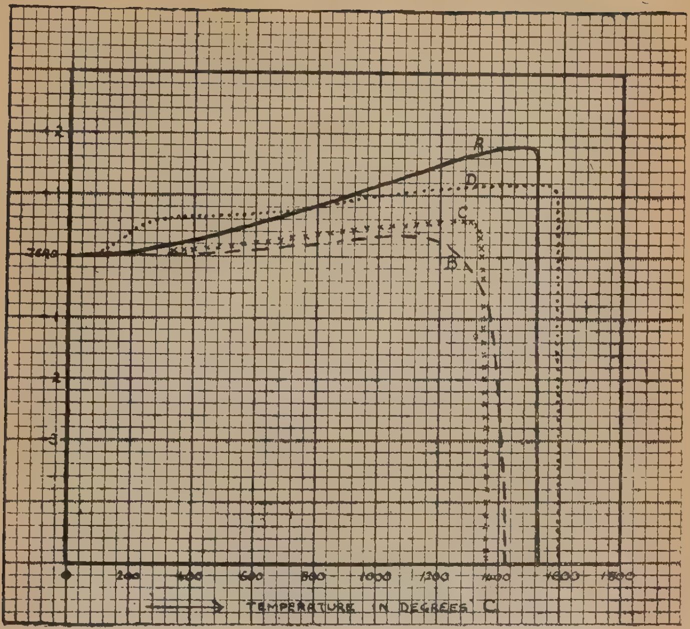


FIG. 3.—BEHAVIOUR OF REFRACTORY MATERIAL UNDER INCREASING TEMPERATURE CONDITIONS.

(The above curves are not true copies of actual results, but are representative.)

A.—Expansion regular and collapse sudden, i.e., softening occurs within a small temperature range. This is advantageous (given by magnesite brick).

B.—Expansion small and even, but collapse is gradual, and softening occupies a wide range of temperature. This is a disadvantage (firebrick).

C.—Also a firebrick, but softening occurs within a smaller temperature range and collapse is more sudden. Note.—Although A softens first, it does not collapse so soon as B, and is therefore regarded as being the more refractory.

D.—An uneven expansion which necessitates careful heating in the neighbourhood of 200 to 300 deg. C. (Comparable with silica brick.)

nection and must be judged by grading and by density (apparent and true) from which the porosity may be deduced. Pore spaces in a brick may be regarded as tiny expansion joints, whence has arisen the idea that a porous brick is less liable to spall than is a dense brick. This is not always true, and it is, in fact, possible to argue that the converse holds.

Density is highly important in another connection. Brickwork has generally to resist mechanical wear, such as abrasion and other factors enumerated previously, and to do this it must be mechanically strong.

Mechanical Strength.

Mechanical strength is to some extent incompatible with high porosity, the former being generally the more important, and indicated in crushing strength and underload tests. It is clear that of two bricks made from identical material and submitted to underload test, that which was badly made would fail at lower temperature. In other words, the cold crushing strength of refractory bricks is important.

Chemical Analysis.

The last, but not the least important criterion is chemical analysis. Generally the only data available when examining refractories are chemical analysis and refractoriness.

Refractory materials can be broadly grouped on a basis of chemical constitution. Three large groups are acid, neutral and basic, terms which, though based on simple chemistry, are far from simple when applied in this connection. In these groups there are smaller groups, such as silica, siliceous, fireclay, chrome, carborundum, bauxite, magnesite. Chemical considerations are primarily of importance in deciding which type of refractory is best suited to resist the chemical conditions of any particular foundry operation. Thus, silica bricks are best suited to withstand the acid and siliceous slags in the acid open-hearth process, whilst for the basic process a basic brick such as magnesite is necessary. Some type of chrome bricks have been found effective in resisting both acid and basic slags, since they are chemically neutral.

Having decided upon the type of refractory needed, the chemical analysis of materials of that group, submitted to the prospective user, is of great value. Each type is characterised by a predominant mineral. Thus silica characterises a silica brick, magnesia a magnesite brick, alumina and silica (jointly) a firebrick. (The term firebrick is generally to be understood as meaning a fireclay brick.)

In "siliceous" bricks and firebricks and cupola patching pastes, the proportion of silica and alumina are of prime importance. The other constituents revealed by analysis are generally—but not always—harmful, and an accurate chemical analysis serves to show whether the predominant mineral will be adversely affected by an excessive amount of other constituents, commonly known as "fluxes."

Since refractories are far from conforming to the ideal, it is essential that they should be selected and used with due regard to their properties, physical and chemical, and the conditions under which they are to be used if the best results are to be obtained. Whilst there are cases, like the acid and basic open hearth, in which chemical considerations definitely call for a particular type of refractory, there are others in which chemical considerations have to give way to others of greater importance.

Refractories generally used in iron foundries may be grouped as follows:—(1) Linings for cupolas and other melting furnaces, and for annealing ovens; (2) ladle linings; (3) refractory sands for moulding; and (4) specialities, such as paints, blackings, compositions, and so forth.

Cupola Linings.

The conditions, enumerated earlier, applying to this case are:—

(*a*) *Intense Heat.*—The temperature is less than that in the open hearth, but is still very high. It may be assumed that refractory linings in cupolas are exposed to a temperature of 1,600 deg. C., with higher temperatures than this locally.

(*b*) *Chemical Action* of basic fluxes such as lime, acid fluxes such as silica, present on all pig-irons, and, in addition, fluorspar, which will flux almost any type of refractory. Add to these, sulphur, and chemical conditions assume a formidable aspect for both acid and basic fluxes are at work.

(*c*) *Physical and Mechanical Conditions.*—Whilst the actual weight on the lining is not great, it has to withstand heavy mechanical wear, due to the descending charge of coke and metal, whether scrap or "pig." In the bosh or well or receiver, the bricks on the slag line are affected by "washing" action, which is as serious mechanically as chemically.

(*d*) *Temperature Changes.*—The arrangement of the charge as it descends may cause a blast of cold air to play at intervals upon a hot face, but more serious still is the fact that the whole lining is heated up quickly, from cold to hot in a few hours, and it is cooled in a similar period at the end of the day's "blow." Linings may even be chilled by a stream of cold water. Few users of cupolas find it possible to work continuously or economical to raise or lower the temperature slowly at the beginning or end of the day. In a few cases, cupolas are worked continuously until the lining demands attention, but even these continuous periods are very short and may be measured in days since cupola linings are at present unsatisfactory.

One might say that in cupolas conditions are less favourable to refractory linings than in any other furnace, and since, from the point of view of the melter, reducing atmospheres are preferable, the lining is sacrificed to the metal.

The atmosphere in a cupola is not easily controllable, since before the CO_2 formed at the tuyere level has risen far it meets hot carbon and is reduced to CO. In the average cupola this CO may be seen burning above the charge, at the charging-door level. Now the heat generated by this burning CO is lost in ordinary cupolas, but it is learnt that in the Poumay modified cupola this waste is avoided, the CO being burnt before it leaves the charge. A diversion here is worth while, since the Poumay cupola will serve as an illustration of how conditions, together with a knowledge of refractory materials, should be studied before final selection is made.

From theoretical considerations one would deduce that the temperature in the melting zone of the Poumay system cupola is lower than that in one of ordinary type. But the atmosphere is deliberately adjusted so as to be "reducing," that part of the air necessary to complete combustion being introduced at a higher level through the small, helically-arranged tuyeres, so that the lower temperature may be more than counterbalanced by the effect of atmosphere. The author is at present investigating the use of special refractories in a Poumay cupola, and is told that the fluxing of the lining, though severe, is no worse than obtained before modification. Results so far obtained, whilst not entirely successful, are sufficiently so to warrant further trials.

Air and Reverberatory Furnaces.

These possess the advantage that the charge with its fluxes is not dragged over the whole lining. The heating flame has an easier passage, since it passes *over*, and not *through*, the charge, and is more regular, and the atmosphere may be oxidising without affecting the metal, since this is protected by a layer of slag. The effect on the slag line refractories will, however, be more severe.

Annealing Ovens.

The most serious requirements are, presumably, air-tight joints and brickwork, having little or no expansion and contraction, both of which would produce disruption of walls and arches.

Ladle Linings.

Whilst fair refractoriness is required, the temperature is only that of molten metal, and there is no cutting flame or effect of "atmosphere." The most serious considerations are:—(*a*) ability to withstand sudden heating and chilling, and (*b*) mechanical strength to resist the "wash" of metal. A special case arises when metal is desulphurised in the ladle, particularly if alkali be used for this purpose.

Moulding Sands.

In iron-moulding sands the foundrymen require:—(1) Refractoriness, in virtue of which the sand is not affected by metal under load, and stripping is thereby facilitated; (2) mechanical strength which is given by "bond"; and (3) permeability to gases escaping from the metal as it cools, and which is by no means the same thing as porosity. It depends on:—(*a*) Grain size and ratio of grain sizes (generally there should be a predominance of two grain sizes, relatively large grains and small grains); and (*b*) bond, which should not be excessive, and should be evenly distributed over each grain.

Silica Sands for Mixing should be high in silica, and therefore refractory, and should have little or no bond, and the grains should be round, even, and approximating to one size, especially if the sand is to be used for core work.

Cupola Linings.

A study of conditions leads to the conclusion that the most satisfactory lining should be:—Neutral; able to withstand temperature changes without spalling; dense; hard; mechanically strong; and refractory.

These requirements have led to the general use of firebricks as cupola linings, a choice which can be justified by consideration of their main features. They are, moreover, among the cheapest of refractories. It still remains to be proved that more expensive, special refractories, such as chrome, magnesite, carborundum, can be used with true economy, that is, with reduction in cost per ton of metal melted.

Now firebricks are only neutral in the sense that silica and alumina, acid and base, are present in chemically-equivalent proportions, and the ideal firebrick contains these two constituents in such proportion that neither is present in excess (*i.e.*, in the "free" or uncombined state). In such bricks the percentage of alumina will not be below 35 per cent., and will generally be above this figure.

Since excess silica will generally be present in the free or uncombined state it is liable to expand when the brick is in use, and the tendency to spalling is thereby increased. The burning of firebricks in manufacture is not generally designed to convert the free silica to forms in which its expansion is not so serious. The presence of free alumina is not always an advantage, although high alumina bricks are generally more refractory than those containing 35 per cent. or less. Many firebricks are made from mixtures of ordinary fireclay with bauxite or bauxitic clays, both of which are rich in Al_2O_3. This mixing of two different materials, which may have different expansions, means that temperature changes may disintegrate the brick. This is not to be interpreted as a sweeping condemnation of this practice since wise makers carefully select the clays to be mixed and, whether by research or by trial and error, they find clays which will blend satisfactorily. It is, however, advisable not to be blindly enthusiastic about high alumina bricks as they are more expensive than ordinary firebricks and often give no better service in use.

Firebricks quite commonly develop sillimanite ($Al_2O_3 . SiO_2$) and mullite ($3Al_2O_3 . 2SiO_2$) during use in furnaces, and these minerals are now receiving attention as refractory materials. They are formed in firebricks by inter-reaction of silica and alumina under continued high temperatures, and are characterised by high refractoriness and very low thermal expansion. Whilst part of the value of high alumina firebricks may be due to the probable formation of these minerals, this is not to be read as an assertion that sillimanite or mullite bricks (high-priced specialities) will prove successful as cupola linings. Quite the converse is indicated by the author's present knowledge.

So that, in selecting firebricks for cupola lining, the ratio of silica to alumina, as revealed by chemical analysis, is worthy of serious consideration. To derive real benefit from such considerations, however, a full knowledge of the chemistry of clays and mixtures of silica and alumina is necessary and it is doubtful whether research has proceeded far enough to standardise any conclusions in this matter. There are, moreover, firebricks in which the SiO_2/Al_2O_3 ratio does not satisfy any of the foregoing rather debatable points, and which give good service in cupola linings. The purchaser can rarely be expected to go into all this and generally wants simpler considerations.

It is essential in judging the merits of a firebrick to note that silica and alumina are the main constituents. Silica may be present in quantities ranging from 80 to 55 per cent., alumina from 10 to 45 per cent., these figures being only approximate. If alumina is above 35 per cent. the bricks are generally higher in price. It is clear that the analysis of a firebrick should show that silica and alumina are the main constituents and the total of their percentages in good bricks will not generally be below 94 per cent. The rest of the constituents are known as fluxes, and are undesirable, though to some extent essential, since they bind the brick particles together. They include ferric oxide, lime, magnesia, titanium oxide and alkalies, and the following maxima may serve as a guide in selection:—Fe_2O_3, 2.5; CaO, 1 to 1.5; MgO, 0.5 to 1; TiO_2, 1.5; and alkalies (Na_2O and K_2O), 1 to 1.5 per cent. Ferrous oxide, present in the raw clay, is generally oxidised in making. Fe_2O_3 is the most important flux if reducing atmospheres are likely to be met. A firebrick in which total fluxes comprise more than 6 per cent. would be regarded with suspicion.

A second consideration is refractoriness, and it may be assumed that a satisfactory analysis will lead to high refractoriness (in the neighbourhood of 1,700 deg. C. in ordinary test). The ordinary refractoriness figure is apparently well above furnace temperature, and one wonders why such bricks fail. Firebricks are soft, and readily collapse under loads of 50 lbs. per sq. in. at temperatures far below that which indicates their refractoriness. The under-load test is most valuable here, but not all manufacturers offer such data on their materials. A good class firebrick will collapse in the neighbourhood of 1,450 deg. C. under load of 50 lbs. per sq. in. Very good bricks would withstand 1,500 deg. C. Now this is apt to cause alarm when one considers a furnace temperature of 1,550 deg. C. to 1,600 deg. C., but the following considerations account for such life as is obtained from firebrick linings:—(*a*) The weight is rarely 50 lbs. per sq. in. In a firebrick wall, 20 ft. high, the weight on the bottom course would only be 20 to 25 lbs. per sq. in., and (*b*) it is only the inner face of the wall which is at the higher temperature, and the weight will be carried by cooler parts nearer to the shell of the furnace.

But this softening effect on the bricks is serious since the hot inner face is liable to be soft enough to hold particles of corrosive ash, dust, silica, lime, etc., and may, indeed, be so soft that the descending charge tears it away. It is quite apparent that the ideal refractory would have a high crushing strength at the temperatures met in industrial furnaces. So that, wherever figures are available, it is refractoriness under load which must be considered and that brick with the highest figure selected—other considerations being equal.

The expansion curve under load is valuable as indicating the ability of the material to withstand the temperature changes. It has been shown that this ability is estimated by expansion, proportion of "glass" in the brick, the texture, and porosity. A high expansion, or an irregular one —which can be illustrated in the expansion curves under load (Fig. 3)—will most certainly cause trouble in this connection. Firebricks are generally well able to resist spalling.

Conditions in a cupola call for dense bricks which will be mechanically strong, and will resist wear and tear due to the descending charge. They will, moreover, be less liable to penetration by fluxes. A difficulty arises here, namely, that a dense brick is more likely to spall, and selection calls for wise balance of judgment. It is arguable that a fairly porous brick could be selected from considerations of spalling tendencies, and its face protected from penetration by dust and slag by the application of a highly refractory, hard and dense, slag-resisting wash or coating, generally applied as a finely ground cement.

In the upper part of a cupola, mechanical wear and tear is very severe, and whilst at the charge-hole level, metallic blocks can be used to meet the impact of charge, between these and the melting zone very dense bricks are needed, density being here more important than refractoriness. It thus appears that at least two types of bricks could be used with advantage in the cupola. Whilst this would be inconvenient and call for special care it might be well worth while.

Ramming of Cupolas.

This is frequently used as the method of lining nowadays, and the compositions to be used must be selected with due regard to the conditions I have outlined. The main advantages of a rammed lining appear to be:—(1) Absence of joints; (2) ease with which lining is effected, and (3) repairs effected by same material, so that there is only need for one material in stock. The disadvantages would seem to be:—(1) Difficulty in drying, and disruption of the lining may follow rapid drying or melting before lining is dry, and (2) the front face of the lining is thoroughly sintered by heat but the inner parts (nearer the shell) may be friable.

If the chemical analysis of the ramming material is satisfactory, the important features to be considered are: grading, bond, and "set," when rammed hard and dried. The "bond" must be sufficient to bind the coarse particles together and no more. The bonding material must set on drying to produce a hard mass. Grading or size of the coarse refractory particles is important in producing a mass which is sufficiently porous to dry easily, and sufficiently coarse to allow easy ramming without formation of air pockets. Grading has great influence on hardness of the dried mass. A mass of particles poorly graded will require more bond than the correctly graded mixture, and it is to be remembered that this bond is at the same time a "flux" whose function it is to bind the more refractory particles together. The coarser particles should preferably be calcined so that any permanent shrinkage or expansion is removed, and they may be either siliceous or fireclay material.

Thus, the production of a satisfactory ramming composition calls for great care and wise application of knowledge. A good composition for this purpose will not, therefore, be cheap, that is, as cheap as the common patching ganisters and compositions. The prime cost of the ramming material considerably affects the economic value of this method of lining and there does not seem to be sufficient information on which to base definite conclusions as yet.

Since the main objection to brick linings is regarded as joints it seems that more attention to these and the materials used in them would prove quite as profitable a line of investigation as that of ramming. With perfect joints, a brick lining can be set so as to constitute a one-piece lining. There is no drying or shrinkage problem; the lining is hard throughout, has been pre-shrunk or expanded as the case may be, and requires no heat to sinter it into hardness.

Very similar remarks apply to the ganisters and specialities offered for patching pastes; these are generally of finer texture than the ramming materials and should be selected just as carefully.

The commoner ramming compositions and patching pastes are siliceous, but could just as well be of fireclay. Theoretically one would expect a silica lining to be more susceptible to lime than is a fireclay, but experience in cupolas shows very little difference. Cupolas are, however, frequently bricked with "siliceous" bricks containing 80 to 85 per cent. SiO_2 and 8 to 10 per cent. Al_2O3, of similar composition to ground ganister. They are frequently called "ganister" bricks, and the term "siliceous" includes "semi-silica" bricks. From the high free silica content one would expect these bricks to spall, but they often give good service. The non-spalling qualities of some bricks in this class has been attributed to the fact that the clay is present in sufficient quantity to compensate by its shrinkage for the expansion of the silica. Such an explanation is not always tenable, but there are others which it would not be profitable to discuss here.

This leads to a consideration of the possible use of silica bricks in cupola linings. A silica brick is characterised by about 95 per cent. silica, 1½ per cent. lime and very little else. Theoretically these bricks would be rejected on account of high thermal expansion which should cause spalling, and they are, moreover, distinctly "acid" and therefore susceptible to lime, which is, in fact, used in bonding the brick. The author would be glad of any information on this point as, so far as he knows, only one firm is using lime-bonded silica bricks for lining a cupola. He has no details as to manner of working, or results obtained, but he would suggest that with the properties of these bricks in mind, they are unsuitable for lining cupolas which are worked intermittently. There are wide differences between different makes of this class of brick, and one type he has in mind has certainly very low spalling propensities—as is proved by its use in regenerators and checkers.

Special Refractories for Cupolas.

Whilst there are references in technical literature to the use of such special refractories as chrome, magnesite and bauxite in cupola linings, the subject has not been fully investigated. These materials may fail when tried in the usual form, but may possibly be specially adapted so as to give better results.

One further essential in cupola refractories is that the bricks and blocks used must be of good shape and regular in size, and must be carefully jointed with good jointing material. There is no doubt that joints are usually the starting point for slag penetration and wearing of the linings.

For Air Furnaces the selection of firebricks is to be made with the same care. It is still more practicable in this case to use bricks of medium porosity and low spalling tendency, for roof and side walls, and then to close the pores by a refractory coating on the face. Only the highest class firebrick should be used. Special refractories, though very expensive, might yet be worth while in this case.

Annealing Ovens. These do not generally call for the highest grade firebrick yet selection here should be made with due regard for conditions. When these are considered it will be seen that in view of the alternate heating and cooling silica bricks are most likely to spall. With ordinary care firebricks, carefully built, will give such a long life as does not warrant the use of special, high-priced refractories. Joints are often the weakness here because temperature is not high enough to glaze the fireclay commonly used, which, in consequence, imparts no mechanical strength to the structure and renders the joints very weak in addition to being leaky, admitting air, etc. In a case like this it is best to use one of the cold setting cements, or a less-refractory clay.

Ladles.

It is a strange circumstance that the best quality firebricks often fail in a ladle lining.

Remarkably good results have been obtained by the use of firebricks made from rather poor fireclay and underburnt. The explanation would seem to be that an underburnt firebrick contains no "glassy" material, which is a feature of all well-burnt bricks, and, of course, spalls under the sudden temperature changes in a ladle. In iron foundries, however, ladles are more commonly lined with loam, ground ganister, and specialities. These must be fairly refractory, must dry hard (not friable), must dry without shrinkage. Ideally, they should be just so refractory that the heat of the metal sinters the skin.

In some foundries it is usual to desulphurise in the ladle, and this may be effected by the use of carbonate of soda or specialities incorporating this material. But the alkali very quickly attacks a loam, firebrick, or ganister lining, and in one or two places desulphurising by this method is not adopted simply because of lining troubles. It is possible, however, to use specially made compositions which have been known to increase the number of heats in desulphurising from 5 to 200.

Silica Sands.

Silica sands, generally used for cores and for mixing with strong-bonded moulding sands, should be as nearly pure silica as possible. They should be free from bond, the grains round, and all approximating to the same size. In this way maximum permeability is ensured. The grain size should be chosen to suit the class of work on which the sands are to be used.

Moulding Sands.

These are characterised by high silica content, but must also possess bond, which is given by both alumina and ferric oxide. A bond due to hydrated or colloidal Fe_2O_3 is to be preferred to that given by clay, since the bonding power of the former is not so easily destroyed by heat as in the case of the latter. Sands whose bond is colloidal ferric oxide do not tend to become "spent" so soon as those bonded by clayey matter. The content of ferric oxide is not harmful in this case, since there is no effect due to "atmosphere." Bond should be evenly spread over all grains; there should be sufficient to give strength and no more, except in the case of sands to be used as renovators. Fluxes, as shown by chemical analysis, should be low. Selection should always be made from such sources as can be relied upon for regular and uniform deliveries. A high-class sand is of no use if only available occasionally.

The Use of Refractory Materials.

No matter how wise and successful the selection, the last word is said by the user—that is, the actual furnace operator, melter, or moulder, who can make or mar the best materials, and who can achieve wonders from material which is theoretically poor. Respect for these users is increased when it is remembered that they have done their job for years without any theoretical knowledge, such as the technology of refractory materials. To some extent they work by "rule of thumb," and their knowledge of the different treatment refractories will withstand is based on actual experience, and not on any theoretical chemical and physical knowledge.

The technologist, in one sense, seeks to find the reasons for the conclusions reached by the practical man, and in making his pronouncements and opinions should show deference to practical experience. Knowledge of refractory materials is so little advanced that theoretical conclusions are often shattered in a practical test. The practical man should not, on the other hand, despise the theorist, since technology aims at such grouping of practical conclusions that general rules are formed by which the knowledge gained by experience can be imparted to a learner in a few years.

Refractory materials are most likely to give full satisfaction when the theorist and practical man work together. Each should try to appreciate the other's point of view, and the practical man will benefit just as much by a knowledge of technology as will the technologist by practical experience.

Since the "user" has such power, he has also great responsibility, and he should see to it that refractories are used with due regard for their properties. In other words, the farther refractories are from the ideal, the greater endeavour should be made to "give them a chance."

Bricks should be handled carefully. The author often contrasts the meticulous care with which one handles postage stamps, and the annoyance one shows if a penny stamp is torn, with the rough and careless handling which firebricks receive. The cheapest firebricks cost more than a penny each, but magnesite bricks, worth 1s. 6d. each, are often handled as though they were common building bricks. The manufacturer is horrified as he sees the shapes, the perfecting of which has haunted him night and day, being broken on corners and edges by careless handling. Bricks should be carefully handled, not merely so as to avoid grieving the supplier, but because, with damaged edges and corners, it is impossible to build furnace walls, in which joints are so thin as to be almost invisible.

New brickwork and patching should be perfectly dry before heating—a point not always appreciated. It is arguable that refractory bricks, like common bricks, give better and stronger walls if they are wetted before being set in fireclay or cement. This is worth careful investigation, as it receives support from researches into the effect of using wet grog in firebrick manufacture. If such practice is followed, the drying before firing must be the more thorough. Patching materials should be applied with the minimum of moisture, must not be applied to glazed or slagged surfaces, the surface to be patched being cleaned or "scrappled," so as to enable new material to "key" on to the old brickwork. The cleaned surface must be wetted, preferably with a thin wash of the material, before the stiff paste is applied. Patching materials should be applied in as thin layers as possible, and the thicker the patch the coarser the materials. Finely-ground material should be carefully vented.

In some foundries the cupola lining is cooled by a spray of cold water or a dusting of lime at the end of the day. This is not giving the linings a chance, and though it may be essential in some cases, it is apparent that another cupola is called for.

Linings can be quickly ruined by the use of excessive flux, such as limestone and fluorspar, and these should, of course, be used in the minimum quantities consistent with requirements in the metal. Metal a little cooler and slag slightly more viscous may be less costly than the wear and tear of linings.

Careful charging of a cupola will produce that regular and even arrangement of charge which will facilitate passage of blast and preserve the lining, in addition to producing more efficient melting. Ladles should, of course, be pre-heated wherever possible, so as to reduce the thermal shock to the lining.

If the most refractory and the densest firebricks are selected with a view to resisting heat and slag action, it is clear that they must not be encouraged to spall and *shattered by sudden heating and cooling*.

Moulding sands should be used with the utmost care, being well mixed and well milled so as to spread the bond uniformly, and carefully rammed, neither too hard nor too soft. Excessive "sleeking" brings clay and silt to the surface of the mould, and refractoriness and permeability are thereby reduced, and "scabbing," "burning on," are caused.

Careful use of furnaces means that less of the lining is reduced to slag, in which both fuel and metal are wasted.

The whole question of selection and use calls for wise judgment and ability to compromise, and the need for knowledge and care, is all the greater, since the demands upon refractories are great in comparison with their ability to meet them.

Wise selection will enable the user to select the right type of material and to discriminate between good and bad supplies of that type. Careful use, on the other hand, will ensure that the material selected will give good service.

Discussion.

The PRESIDENT said Mr. Presswood had covered an extremely wide field on his subject. Personally, he felt that the branch would welcome, on a future occasion, a Paper by the author on one particular aspect of the various matters he had covered in the important question of refractories. They, as men keenly interested in moulding, would be glad to hear the views of a man of the knowledge of Mr. Presswood on, say, sand in the foundry.

MR. WHITTAKER (of Bradford), proposing a vote of thanks to the lecturer, said the address that day had been of fascinating interest alike to the practical foundrymen and the chemists present. Perhaps the majority of the members of the branch were practical foundrymen and they would certainly be glad to hear a Paper by

Mr. Presswood devoted especially to moulding sands.

Mr. W. H. Poole, seconding, said Mr. Presswood had dealt with his vast subject in a manner which all interested in foundry work could appreciate and understand. He had undertaken a difficult subject, but had treated it in a very lucid manner, and had gone through a remarkably extensive range of phases of the subject—a range which was rather astounding in so short a time. Mr. Presswood was to be congratulated on the way he had got the lecture together on so wide a field and had reduced it to an exposition which was simple enough for all concerned to understand without any difficulty.

Mr. Presswood, replying to the vote of thanks, said he had the greatest respect for the men who were the practical users of refractories, but he believed refractories were in many cases not given quite the chance which was their due. He knew that some of the manufacturers at times felt quite grieved at some of the unkind things said about these refractories, because if the refractories were given a little more thoughtful treatment they would return better service. He hoped that anything he had said that evening might do something towards leading to a general better understanding of refractories among the men who used them.

Mr. S. W. Wise (Bradford) said there were certain phases in relation to refractories which were necessarily beyond the experience of the average iron founder, and they looked to technical men like Mr. Presswood to impart guidance and knowledge on these phases. His address and his subject had been of particular interest to the members of the West Yorkshire branch of the Institute because they had recently been discussing the relative merits of rammed lining as against firebrick lining in cupolas. Some members had suspended judgment, and they all realised that there was much to be said in both directions, and much still to be learned. Mr. Presswood's observations seemed rather to suggest that if one had a rammed lining one was practically turning the furnace into a brick kiln. In the experience of most of the members of the branch, rammed linings had proved successful in some foundries, but yet it seemed rather contrary to the theory now put forward, if one could take the material from which firebricks were made and put it into a furnace more or less correctly rammed; the dragging of the template through the length of the furnace must lead to inequality of the ramming. From what they had heard that evening from Mr. Presswood it would not seem feasible that a rammed lining could be as good as a brick lining when put in correctly. Mr. Wise said it would be very beneficial if Mr. Presswood could on some occasion give some further talk on that subject in particular.

Mr. Poole, referring to the question of spalling on a cupola lining, said he believed there was a good deal more of this occurring—apart from actual melting of the brick—than was generally understood. There were more cases of too-refractory patching being put in than of poor refractory patching. For annealing furnaces and for others he had himself, for many years past, made a practice of heavily glazing the brick as a protection against spalling. It was astonishing how much extra life was obtained once a brick was well glazed, and this applied also to the jointing materials. This value of glazing would apply also to rammed linings. Much could be said as to how to perfect a rammed lining to prevent certain troubles which took place in firing it initially. In regard to the question of silica bricks in cupolas, Mr. Poole said there must be pretty continuous running, and under such conditions one could get remarkable life out of silica where a firebrick would fail; but for general foundry work that did not apply. Mr. Poole said he would very much like to hear Mr. Presswood give a lecture on nothing else but moulding sands. The points he had raised as to iron bonding were of very great importance, and they would all like to hear Mr. Presswood in greater detail on that matter. Finally, he asked whether the author could give any idea of a reasonable amount of virgin sand per ton of finished castings, to ensure a really good finish?

Mr. Presswood said suppliers would welcome more information on the cost per ton of castings produced. In two cases of steel castings which he had in mind it had worked out at 25 cwts. of sand per ton of steel. He could not give a figure, off-hand, in regard to iron castings. One heard a great deal about one sand doing one thing and another achieving something else, but he thought it was difficult to arrive at any general basis. Referring to the remarks of Mr. Wise on rammed linings and brick linings, Mr. Presswood said the opinion he had given in the address was his private opinion. If a rammed lining was to be successful there were so many factors to be controlled that it must be prepared so very carefully that its cost was certain to rise. On actual cases of which he was aware, he could not find that it was more economical to put in one or the other at present because of the care required in preparation. In some furnaces rammed linings were essential, and that certainly was so in electrical furnaces.

Mr. Wise, remarking on Mr. Poole's question as to the weight of sand per ton of castings produced, said it must be remembered that the major proportion of virgin sand was in the facing sand, and that that depended on the thickness of the casting. The weight of sand used also depended largely on the character of the casting. Most founders did keep account of the amount of new sand they used per ton of castings produced, and he thought no hard and fast rule could be laid down. Some used 3 to 1 mixture and others a 10 to 1 mixture in a facing sand.

A Member: Something depends on the men and how far the sand mixture is away from the work.

East Midlands Branch.

SHRINKAGE HOLES IN SMALL GREY IRON CASTINGS.

By P. A. Russell, B.Sc. (Member).

The word "shrinkage" is rather misleading, as it carries a narrow meaning of the particular foundry problem under consideration, and preference is given to the word "draw" throughout the Paper. This Paper deals with grey iron exclusively, and, in keeping with personal experience, of comparatively small castings in that metal, made in green-sand moulds. Firstly, there is no general agreement as to the root cause of drawing, and this is of importance, since, if the cause could be found the cure would be much easier to discover.

It is quite a simple matter to the casual observer, who sees it as follows:—cast iron in passing from the liquid to the solid state shrinks, that is, decreases in volume, thereby causing a gap or hole to be left in the casting, unless the deficiency caused by this shrinkage is made up by a fresh supply of liquid metal. This is true in the case of white cast iron, steel, and certain non-ferrous metals. In grey cast iron, however, there is graphite, and this is formed at the same time as the iron is setting. The formation of graphite is accompanied by a very considerable expansion in the bulk of the metal, graphite occupying at least four times more space than that occupied by the carbon in the iron carbide from which it comes. This expansion is sufficient to cause the whole casting to expand as shown by Professor Turner's well-known diagram, which indicated that castings made from Northamptonshire iron show this effect in such a marked degree that the casting does not return to its original size until it is well below red heat.

On the face of it this expansion, due to the formation of graphite, ought to be more than sufficient to counteract the shrinkage of the metal, and the more graphite there is present the more marked should this be. This, however, is contrary to general experience, and the generally accepted view is that drawing occurs somewhat after this manner:—The mould is filled with metal and graphite begins to grow. This causes the whole casting, the outside of which has now partly solidified, to expand to an amount equal to almost all the expansion due to the formation of graphite.

The Phosphorus Eutectic.

The phosphorus that is present in cast iron behaves in a very different way from any of the other substances present. In its pure state phosphorus is a peculiar paste-like substance which burns very easily, in fact, so easily that it sets itself alight at ordinary temperatures. It melts at 44 deg. C. and boils, that is, turns to vapour, at 290 deg. C., a temperature well below red heat. It is obvious that the phosphorus in cast iron cannot exist in this form as free phosphorus or it would all boil away when the iron was melted. It exists as a chemical compound of iron and phosphorus, and this compound of iron and phosphorus attracts a certain amount of pure iron and sometimes some iron carbide, and this goes to make up what we call the phosphorus eutectic. This substance solidifies at 950 deg. C. or at a temperature about 180 deg. C. lower than that at which the whole of the rest of the cast iron is solid, thus remaining fluid considerably longer than the rest of the material. It is important to remember that whatever else happens the whole of the phosphorus present in cast iron occurs in this form and attracts these other things to itself, so that, though the actual amount of phosphorus present may be small, the amount of phosphorus eutectic is always from 10 to 15 times this amount by weight, and considerably more than that in bulk.

Conditions During Solidification.

A casting shortly after being poured consists of these four things—the Austenite crystals, liquid of similar composition, the solid graphite and the liquid phosphorus eutectic. This casting is now considerably expanded, and a large amount of the expansion, that ought to be so helpful in counteracting the shrinkage, has taken place, while a very large proportion of the casting is still liquid. The shrinkage of the solidifying liquid still takes place, and the liquid is not now sufficient to fill all the space inside the casting, leaving a shrinkage or draw hole. This hole occurs, naturally, at the part of the casting last to freeze, which is the place where the heat is dissipated most slowly.

Thus far most authorities agree, although a few have very different ideas. Some state that if cast iron is poured into a mould of sufficient rigidity to prevent the casting from expanding outwards, thus making all the expansion go inwards to correct the shrinkage, the net result is that there is no total shrinkage; but others, notably J. Longden, state that even then there is about 1½ per cent. of net shrinkage, as compared with 4½ per cent., if the casting is allowed to expand freely.

Rate of Cooling.

An important consideration in this connection is the rate at which a casting cools. This is not at first apparent, but imagine the casting to freeze almost instantaneously, and it will be seen that the still liquid portion of the casting at the critical half-liquid, half-solid state will not have time to travel to its natural position, but will freeze where it is at the moment—that is, with the mould completely full. Thus any shrinkage that does occur will occur locally in each crystal, and not as a comparatively large cavity in one place in the casting. True, the shrinkage holes will probably be there, but will be distributed so evenly that they are not revealed even, in most cases, under microscopic examination. It is presumed this is because the shrinkage holes occur alongside the graphite flakes, and are thus not detectable, and also practically harmless. Therefore, other things being equal, and the design and subsequent purpose of the casting permitting, the quicker a casting is cooled through its critical period the sounder the casting will be. This critical period is from the first moment the casting begins to set to the time when the phosphorus eutectic has solidified.

Effect of Composition.

In the same connection the composition of the metal is important. Very soft irons containing much silicon are very liable to drawing, as these irons have a very wide range of temperature from the beginning of their solidification to the end. The presence of much phosphorus is also important, as this, of course, prolongs the freezing range very considerably. Manganese, on the other hand, shortens the freezing range and is very helpful, so that the more manganese there is present, at any rate, up to 1 per cent., the less tendency there is for the shrinkage to occur as draw-holes. Cast iron, to be really free from serious trouble from drawing, should contain less than 2 per cent. of silicon and 0.7 per cent. of phosphorus, with manganese greater than 0.6 per cent. and total carbon higher than 3.1 per cent., but not too high. The amount of silicon indicated may vary according to the section of the casting. In very thick castings the silicon must be less, and in very thin ones it may be more. Iron of this composition is, unfortunately, not always commercially possible, and is, in addition, unsuitable for certain classes of work. The average

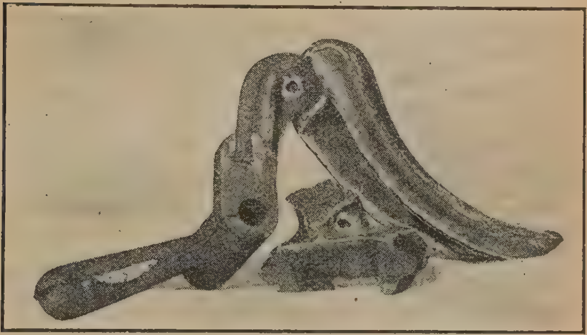


FIG. 1.

founder, using cheap pig-irons, can do little in this connection beyond making sure that the average manganese content of his castings is kept well above 0.6 per cent., and by using as low a silicon iron as the size and subsequent use of his castings will permit. There is one other reason why soft irons exhibit this tendency to draw, that is, that the coarse graphite flakes tend to clog the liquid iron and phosphorus eutectic during the critical period, and prevent the filling up of the deficiency caused by the shrinkage by natural feeding from runners and risers.

Drawing of Semi-Steel Cast Iron.

Finally, cast irons of the semi-steel type give great trouble in this connection, in spite of the fact that the silicon and phosphorus contents of these irons are well below those of the normal common grey-iron castings.

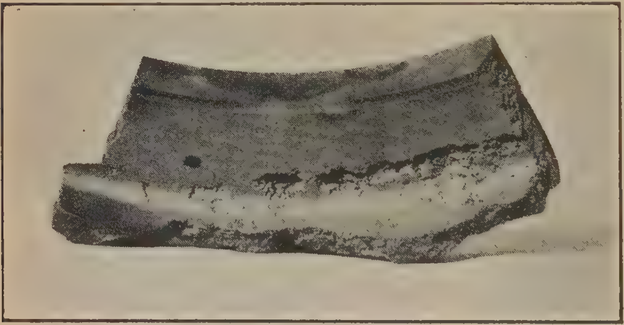


FIG. 2.

The trouble with these appears to be due, firstly, to the fact that their freezing point is higher because of the low total-carbon content, so that the runners and risers freeze sooner; and, secondly, they are much more liable to trouble through gases. Moreover, according to Fletcher, the liquid metal tends to be very irregularly mixed, so that for a founder to attempt to get out of drawing trouble by reducing the silicon and phosphorus contents of his iron by means of steel additions is merely to get out of the frying pan into the fire, and the fire is ten times worse than the frying pan.

The better way is by the introduction or increased use of scrap iron which is almost invariably lower in silicon and phosphorus than the commoner grades of pig-iron. A rather more expensive way is by using a close grain Scotch pig-iron which has the additional advantage of a fairly high manganese content. If the lack of manganese is the only trouble, there are several comparatively cheap brands of pig-iron on the market with high manganese content which can be used mixed with the ordinary local brands. During the coal strike period the author found it necessary to add manganese in the form of lump-ferro-manganese, using about 10 lbs. of 76 to 80 per cent. of ferro-manganese to the ton, charged into the cupola on top of pig-iron. This had a very good effect, but did not entirely cure the very serious batch of drawing trouble that was experienced at that time.

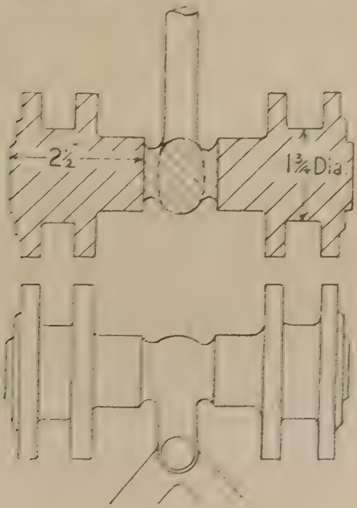


FIG. 3.

Several authorities on the subject attach great importance to the action of gases in causing draw-holes. E. Longden, in one of his Papers on the subject, seems to lay the whole blame for this trouble on mould and metal gases. There is something to be said for this, particularly when using the more sluggish types of cast iron, but it is difficult to agree that this is the whole cause. Fletcher's opinion, as set out in his Paper to the Institute of Mechanical Engineers, is that the actual hole is caused by the pressure of the gases which were dissolved in the iron, and which are released on cooling. There is much evidence in favour of this, particularly when using irons that are liable to give off quantities of gas on cooling, such as semi-steels and cast irons made from pig-irons which have been produced in blast furnaces working under bad conditions.

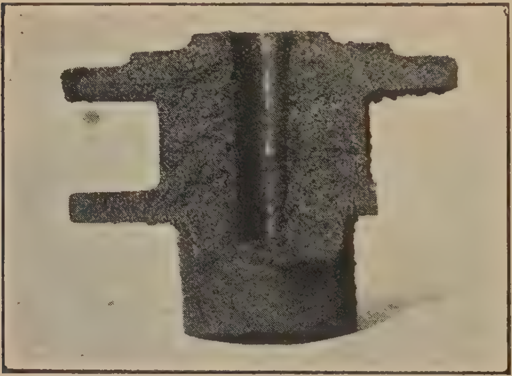


Fig. 4.

On one point practically all the authorities agree, and that is, that at any rate within normal limits, the hotter the metal is poured the more likely the casting is to be sound. The main reason for this is that it assists natural feeding *via* the runners and risers, and tends to even up the temperature conditions of the mould.

Practical Examples.

The foundry in which the author has had most of his experience is a separate unit from his firm's main foundry, and produces principally castings of comparatively small size, that is, from 1 lb. to 56 lbs. in weight and of such size that the boxes in which they are made can be handled, usually by one man alone, and at the outside by two men. They are also examples of semi-repetition castings, which are made principally on hand-ram moulding machines by semi-skilled labour. The quantities off each pattern are comparatively small, and in some cases do not exceed one day's work for a man, so that it is usually impossible to go to great trouble in ascertaining the best method of running the castings. Also, the work being of a "jobbing" nature, and many varieties of castings being made in the same foundry, the quality of the iron used has to be regulated so that the thinnest castings which may be only $\frac{1}{8}$-in. thick may be sufficiently soft to allow of free machining. This condition in the particular class of work under consideration is of great importance. Only one cupola is available, and it is only found practicable to run three qualities of iron each day, so that one is forced to use iron of a composition that is really unsuitable for certain classes of work. The three qualities

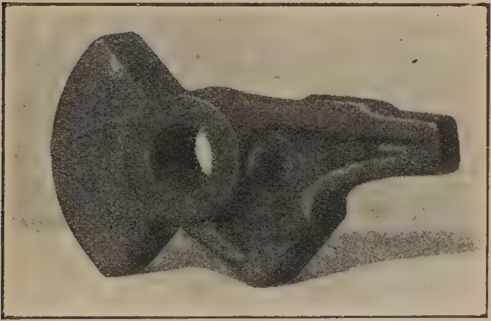


Fig. 5.

used are soft iron with silicon about 2.8 per cent., and phosphorus 1.3 per cent.; ordinary quality, with about 0.2 per cent. less silicon and semi-steel.

Considerable trouble is experienced if the ordinary quality of iron varies very much, the normal difficulty being that for the heavier castings, particularly those of a design very susceptible to drawing, the iron is of too soft a nature. Trouble also arises if for any reason there is a deficiency of manganese in the iron. It is noticeable that a very considerable loss of manganese is incurred in melting the first few charges, particularly the first, which may lose 0.2 per cent. more than normal. This iron is also cooler, and therefore doubly liable to drawing trouble. Table I shows the analysis of various castings that have drawn, certain of which will be discussed with illustrations later. The first item shows an iron which is totally unsuitable for a casting of its nature, namely, a ring about 2 ft. diameter and an average thickness of $\frac{3}{4}$ in. The combined carbon is almost absent, whilst the silicon is very high and manganese on the low side. The second is a moderately heavy casting, and the analysis is again rather on the soft side. The trouble with this was probably more due to cold pouring than to composition. The third is of a comparatively light casting with a heavy boss. The silicon again is too high, and with normal quality iron this casting gave no trouble. The fourth is an obvious case, and is taken from some figures obtained a good while ago when trouble was being experienced with drawing. Except for the comparatively low phosphorus, which does not seriously help, the analysis is about as bad as it could be.

The last set of figures is from a casting probably run the wrong way. This set is the most interesting because the same casting was sound when it was run under apparently the same conditions, but with an iron containing 0.13 per cent. less total carbon, 0.2 per cent. less silicon, and other elements practically the same.

A Belt-Fork Defect.

This casting, Fig. 1, is the one analysed, and shown as item *5a* in Table I. It is a peculiarly-shaped belt-fork, 12 in. overall, and weighing

6 lb., and is cast the way up shown in the illustration. The draw-hole is obvious, and a broken part of another casting is shown with the same defect. The runner is shown on the handle whitened. The cause of the draw is obvious, the thinner sections of metal draining the still liquid metal from the heavy lump at the top of the casting. The resulting gap in the metal comes to the surface because the sand near to it is almost entirely surrounded by metal, and becomes as hot as the metal itself. Casting the other way up would almost certainly have eliminated the trouble, but the method used was by far the easiest from a moulding point of view. A large number of castings were made successfully in this manner, and the trouble only appeared when the iron used was softer, as explained in Table I. Castings made with the composition shown in analysis *5b* were sound.

TABLE I.

Sample number.	Total carbon.	Combined carbon.	Graphite carbon.	Silicon.	Sulphur.	Manganese.	Phosphorus.
1	3.08	0.07	3.01	3.0	0.09	0.49	1.25
2	3.15	0.46	2.69	2.57	0.10	0.58	1.36
3	3.28	0.40	2.88	2.84	0.08	0.57	1.24
4	3.08	—	—	3.13	0.08	0.28	0.7
5a Drawn	3.30	0.40	2.90	2.8	0.08	0.57	1.24
5b Not drawn	3.17	0.40	2.77	2.6	0.09	0.58	1.20

A Ring Casting.

Fig. 2 shows a portion of the ring casting, the analysis of which is given in Item 1 of Table I. The defect was only obvious on machining. When cutting into the corner of the re-entrant angle this large porous cavity was exposed. Gas does not seem to have played any part in the formation of this draw, in which can be observed the rough surface produced by the original crystals, from which the still liquid portions of the metal have been drained away to feed other parts of the casting.

The metal in the casting was about 1 in. thick in the heavier portion. The prime consideration in castings of semi-steel is strength and resistance to wear. The semi-steel produced by the author's firm has to be freely machinable and have a tensile strength of 15 tons per sq. in. The average analysis of this material is:—Total carbon, 2.9; combined carbon, 0.6; graphitic carbon, 2.3; silicon, 2.0; manganese, 0.7; sulphur, 0.11; and phosphorus, 0.9 per cent.

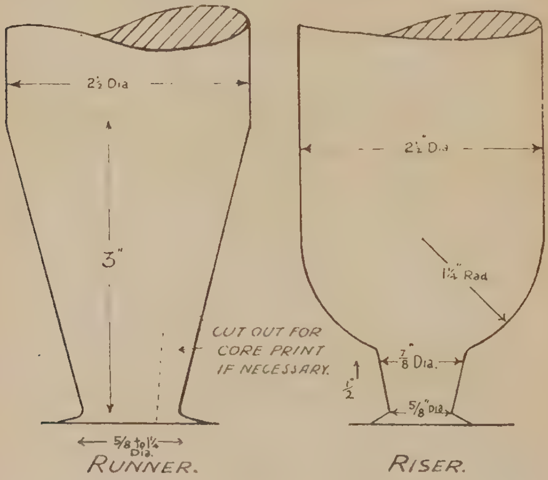


Fig. 6.

It is very much inclined to drawing trouble due to its low total carbon content, its sluggishness and its liability to evolve gas on freezing. It is always necessary to consider specially the running and rate of cooling of semi-steel castings. It is essential that this material should be melted quickly and hot, and then poured hot. There is grave liability of lack of uniformity in the metal, and care must be taken that one tap does not contain all the pig-iron and the next most of the steel. As test requirements have to be met, little alteration can be made in the analysis to prevent drawing, except to combine the manganese at a high figure. So much for the composition of the metal. In a foundry where the design and the patternmaking is entirely beyond the foundry's control, a good many instances occur of castings that are very difficult to make sound, whatever composition of metal is used. There are two well-defined methods of dealing with this problem—careful running and feeding, and control of the cooling of the casting by means of metal chills or denseners. In moderate cases judicious arrangement of the runners is sufficient. There are two distinct ways of doing this. Firstly, by using the runner as a feeder, running into the heavy part, with the down-runner immediately on top of the gate (if any), and secondly, by running into the lighter

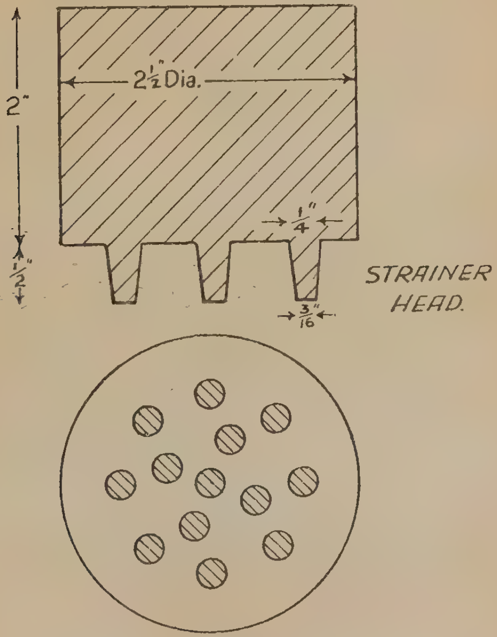


FIG. 7.

part of the casting, and so distributing the rate of cooling more evenly throughout the casting. Nothing between the two should be attempted. In addition there is the possibility of using a riser over the heavy part.

An example of feeding by the risers is shown in Fig. 2. Fig. 3 shows a twin pattern for a

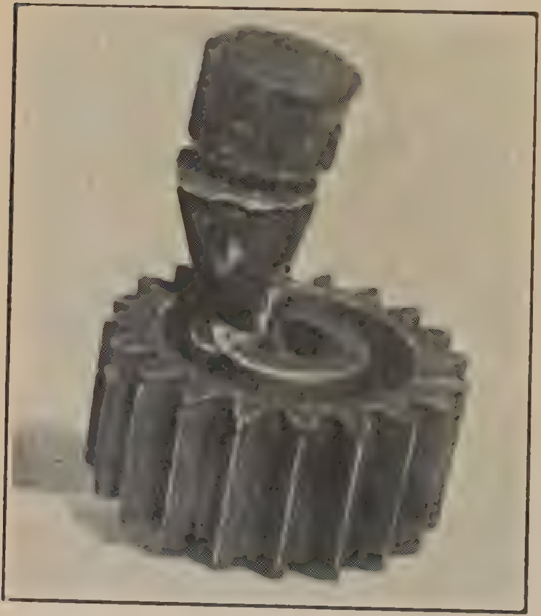


FIG. 8.

small double-flange pulley. The main dimensions are shown and the drawing is to scale. The pulley is bored for the spindle from the solid, and must be sound all over, including inside the bore. The method shown gave a sound casting, and other light castings could be run in same box. It is essential that the downright should be kept close to the castings. This could, of course, be made the other way up, but such a method would involve the use of the core.

Fig. 4 shows the resulting casting drilled and split, and is obviously sound.

Fig. 5 is an excellent example of this problem. The casting is 7 in. overall, and $1\frac{1}{2}$ in. thick at the heavy end. It is too small to be accommodated in a box by itself. Only one pattern is provided, and the quantity ordered is not sufficient to warrant the making of duplicates, so that it has to be made with other castings. The running of this casting has been tried in several ways, principally running with a large runner into the lump or a comparatively small runner at the small end. This latter method was by far the more successful, as, if the composition of the iron was within reasonable limits, the heating up of the mould caused by the metal running through the runner and that end of the mould was sufficient to equalise the rate of cooling, and the resulting castings were sound. This method had the additional advantage of proving success-

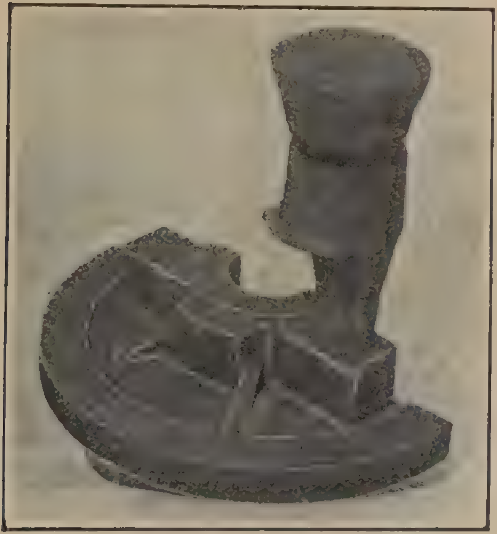


Fig. 9.

ful regardless of the contents of the remainder of the moulding box, provided they were not too heavy. For general work in cast iron of reasonable composition these methods are usually sufficient. A riser may be placed over a heavy part of the casting and frequently helps the casting to be sound. The author places little faith in the ordinary types of riser, where a hole about $\frac{5}{8}$-in. diameter is made by a tube, and then a head placed some 3 or 4 in. above the heavy part of the casting. He has known many cases where the addition of a riser of this type has merely aggravated the trouble by acting as a thin section drawing metal from the thick. The main function of this type of riser is to enable metal to be run through the mould, thus keeping the natural feeding channels of the runner open for a longer time. A runner is a far better feeder than a riser, for the simple fact that the whole

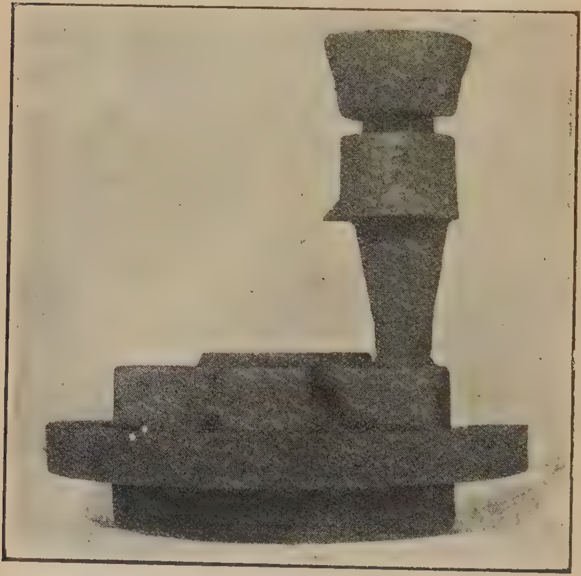


Fig. 10.

of the metal poured into the mould has passed through it and heated up the surrounding sand. At the same time the metal in the runner is fresh from the shank and hot, whereas the metal in the riser has traversed the whole mould and is very distinctly cooler, and thus much less suitable for feeding. The difficulty with feeding by runner or riser is the long parallel stem between the head and the casting, which sets before the runner has fed the casting. Rod-feeding, of course, is of use here, the feeding-rod keeping this passage open so that the liquid metal from the head may be passed into the casting. Rod-feeding, however, is a tedious matter, and almost impossible on repetition work, though there are castings which could not be obtained consistently sound without it. To avoid rod-feeding, runners and risers of the type shown in Fig. 6 are used. Combined with a head of metal above them they will keep liquid in the centre longer than most castings. The two styles are to some extent interchangeable, though when the right-hand one is used as a runner there is

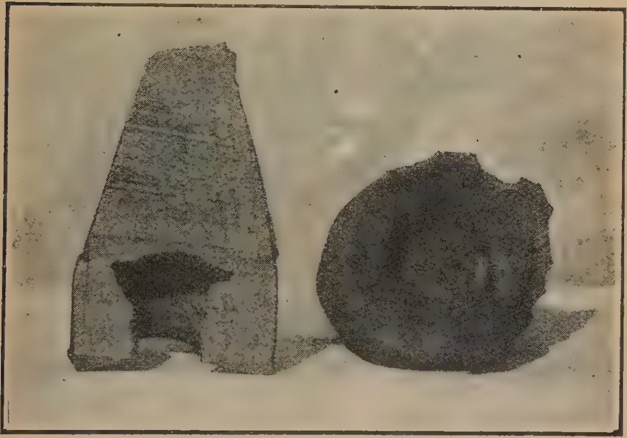


Fig. 11.

a risk of the small neck of sand being washed away by the metal. On the whole the type on the left is more suitable for placing on a boss or above a deep part of the casting, while the other is for placing on a casting of fairly uniform thickness. The advantage of the latter is that there is less tendency for a pipe to form in the neck, which, of course, runs into the casting and produces a defect. The formation of this pipe is the greatest trouble of this type of runner or riser. When it does occur, which is, fortunately,

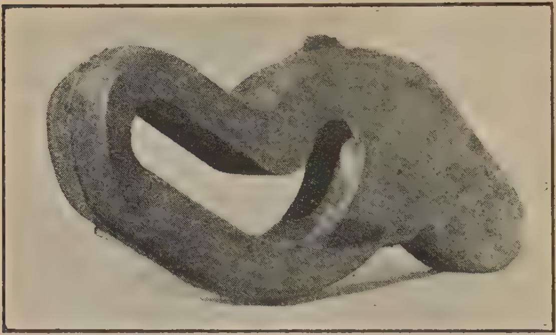


Fig. 12.

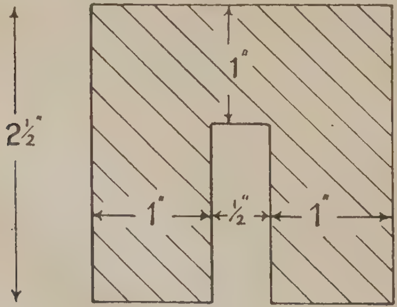


Fig. 13.

infrequently, it can usually be overcome by varying the bottom diameter. The author cannot, in the present state of his experience, give any definite information regarding the correct bottom diameter for different classes of work, but usually the larger the diameter the better. In certain cases the bottom may be rectangular instead of circular. These runners and risers should always be formed by a peg, and not cut by hand, as the latter method is tedious and does not give consistent results.

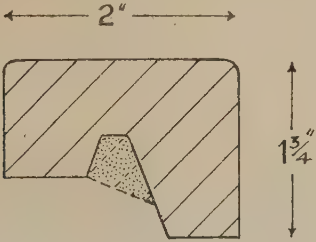


Fig. 14.

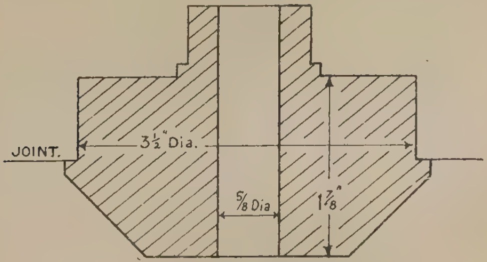


Fig. 15.

The Use of Strainers.

When using a downright of this type as a runner some form of strainer must be used on top of it to prevent slag from entering the mould. Such a strainer is shown in Fig. 7, and is formed in an oil-sand core enclosed in a circular cast-iron bush. This method is frankly borrowed from malleable-iron methods, though, fortunately, workers in grey iron have nothing like the amount of difficulty in feeding castings that malleable founders have. The first time this method was introduced in the author's foundry the scrap from drawn and dirty castings in one particular casting was reduced from 40 to 1 per cent. These runners are used particularly for castings in semi-steel, though they can be applied with good effect to ordinary grey-iron castings.

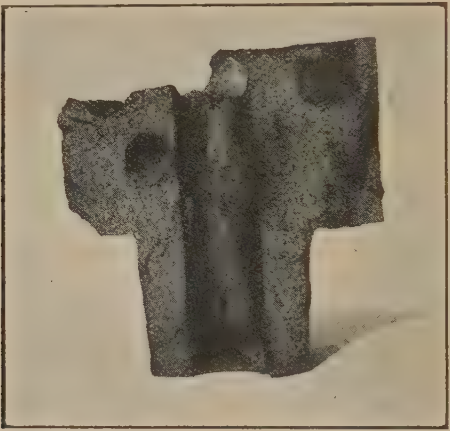


FIG. 16.

Fig. 8 shows a casting of a gear wheel which, previous to the introduction of this method of running, gave trouble through sinking in the recess between the rim and the boss. The gear is 7 in. dia. and weighs 32 lbs. It will be noticed that the downright used is the largest possible, and partly envelops the core print. It is also placed near the small boss so that it is on the heaviest part of the casting.

The casting shown in Fig. 9, also in semi-steel, is for a half chain wheel blank which measures 12 in. overall, has $1\frac{3}{4}$ in. metal in the flange, and weighs 35 lbs. It gave great trouble through drawing in the corners where the web of the wheel joins the boss. Many methods were tried, including internal and external chilling, but none was really successful until the one shown was used.

Fig. 10 shows another view of the same casting, but the runner shows up more clearly. In this case, however, the strainer bush is inverted, and surmounted by an ordinary bush, thus giving additional height to the feeding head, without which the method was not so successful. If the semi-steel is poured reasonably hot no trouble is now experienced with this casting, either from drawing or slag inclusions.

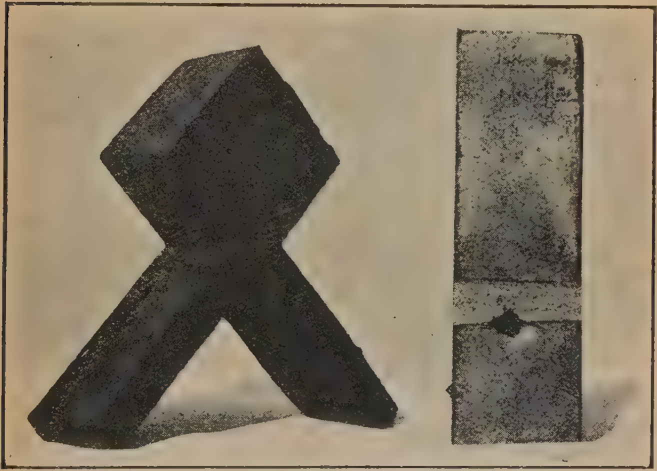


FIG. 17.

The manner in which these runners feed is demonstrated in Fig. 11, which is the downright from a solid block 9 in. × 9 in. × $2\frac{3}{4}$ in., weighing $\frac{1}{2}$ cwt. The draining of the metal from the head is very obvious, and the resulting castings were quite sound. The metal used was the ordinary grade of cast iron, which is really too soft for a block of this section, but the quantity required did not warrant the melting of a special charge. Incidentally, this head seems to prove that drawing is due to pure shrinkage and not to gas pressure, as gas having arrived this far would have escaped.

Link Casting Presents Difficulties.

The link shown in Fig. 12 is 10 in. overall, weighs 10 lbs., and is cast in semi-steel. All types of runner and riser were tried on this casting, and although castings free from sinking were obtained either by a feeder runner straight into the heavy part, or by an ordinary runner into the light end and a feeder type riser on the heavy section, trouble was experienced through piping down the centre of the feeder. Finally, the casting was run at the light end and fed with a rod in the centre of the heavy end. This was successful, but of course tedious and slow. The actual casting shown was run with very hot metal through a $\frac{1}{4}$-in. square runner in an attempt to use Ronceray's method. On first examination, within an hour of casting, the castings were apparently sound, and instructions had already been issued for a full day's work to be made by this method, when the sinking by the core, which can be seen in the photograph, was discovered, fortunately before any moulds had been made. The subsequent use of the casting debars the use of chills, and in view of the difficulties experienced with this casting it would be interesting to learn how a malleable foundry would tackle this prob-

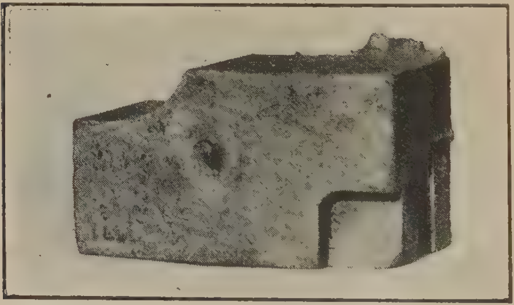


Fig. 18.

lem. The piping trouble mentioned earlier was not consistent, and a great many sound castings were made without rod-feeding.

The presence of the pipe was apparently due either to a slight difference in pouring temperature or to differences in the buttoning of the feeder by the moulder.

Use of Chills.

The alternative method of dealing with drawing trouble is by controlling the rate of cooling so that the different parts of a casting freeze at an equal rate. The use of denseners or chills in this connection is widely known, and does not need to be described here. (The word chill will be used throughout this Paper in this sense only.) There are a few points in connection with the control of the rate of cooling which are not sufficiently widely appreciated. Firstly, it must be clearly understood that the fact that a projecting portion of sand takes weight out of a lump of metal, does not apparently alter its rate of cooling and often aggravates the trouble by taking the surface of the casting right into its heart, where the defect will show itself. Fig. 13 will make this clearer. The sand of the slot core will be heated up to the temperature of the metal, so that the part of the casting shown cannot be considered as consisting of metal 1 in. thick, but as a piece $2\frac{1}{2}$ in. square, which is an entirely different proposition when

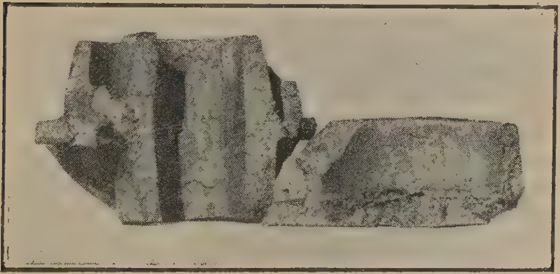


Fig. 19.

considering the rate of cooling. This is, of course, an extreme case, but the principle applies in cases much less obvious.

Fig. 14 is a typical example. It is the section of a casting for a rubber mould, and as such has to machine up bright all over the inner face. This inner face, in parts, is very much enclosed by metal, and the sand would heat up to such an extent that the casting could be considered from the point of view of the rate of cooling, as consisting of a solid casting of the shape outlined in black. Thus the casting must be run with metal and runners of such a character as to produce a casting which would be sound if the groove were machined out of the solid. There is far too great a tendency to think that by reducing the section of the metal in a similar way to that shown here the casting will machine up sound. The trouble lies not so much in the design as in the founder's methods. The designer cannot alter his casting to any appreciable extent to help the founder in this case.

Another point that is often overlooked, is that the part of the mould over which the metal passes from the runner becomes very much heated up. This hot spot is a very likely place for a draw to appear. This effect must not be overlooked when placing chills. Cases are known where the cooling effect of a chill is entirely neutralised by its being heated up by the passage of much metal over or close to it.

There is one aspect of the use of chills which it is desirable to emphasise. The casting shown, Fig. 15, is for a small bevel gear blank, and the customer supplied two patterns on a board. With two patterns in a box very great difficulty was experienced in producing these castings free from draws from the core. A riser was not sufficient to feed the casting for reasons already stated, and a feeding runner was impossible owing to the thin lip on the joint line. For a long time the only way found to produce the castings free from drawing was to run them the other way up with a feeder runner on the board top-face. This gave some trouble, due to dirty castings on the face of the bevel (this was before the introduction of strainer cores), and was very uneconomical, as it involved making the castings singly.

Finally, a taper chill was used and the original two patterns on a board could be used again, the bevel face could be cast down and castings free from drawing regularly produced. These taper chills are made of steel, turned with a minimum taper of $\frac{1}{4}$ in. per foot and they must be dead smooth. Before being used each day they are dipped into molten gas tar, which prevents their sticking to the casting, and will not cause them to blow. They can be used repeatedly, and their life is governed more by the treatment they receive than by anything else. A soft lead hammer should be used to drive them out, as once they begin to burr up difficulty is encountered, as the steel naturally becomes excessively soft due to the frequent annealing. Efforts to restore them by heat treatment were unsuccessful.

Naturally, the greater the taper permissible the longer the life of such chills. Such is the advantage to be gained by the use of these taper chills, that all heavily-bossed pulleys, etc., are treated in this manner. In some cases the use of the chill obviates the necessity of boring. Only one case of the use of a taper chill making the hole too hard to bore has been encountered here, and that was a $\frac{7}{8}$ in. dia. chill with only $\frac{1}{2}$ in. of metal round it. Here the chill was used to equalise cooling after setting, and not to prevent drawing. Taper chills can be used with equal safety on semi-steel and ordinary grey iron.

Cone Pulleys and Steel Shot and Oil-Sand Cores.

Fig. 16 shows the boss of a cone pulley, of which the smallest of three steps only is shown. It is about 9 in. in its maximum diameter. and the smallest step is 5 in. diameter. A very bad draw-hole is observable in the heavy lump. This could hardly be seen when looking down the core, only a small crack being visible. Taper chills have been used in this job for some time, and not one casting has drawn and no reports of defective bores have been received from the machine shop. The illustration, of course, is of a casting made with an ordinary sand core. An alternative to the use of solid steel-chills is to use steel shot mixed with the oil sand of the core. This method tends to produce a very rough skin, due to partial fusion between the steel shot and the casting, and is not to be recommended for small castings. Fletcher has stated that it was often necessary to use nails cast into the metal to accelerate the cooling of awkward parts of a casting, but he described this method as being essentially wrong. With this the author fails to agree, as he can see no objection to the use of nails, provided no machining takes place where the nail is placed, as the nail tends to form a patch of white iron 'round itself. Surely it is better to produce a casting sound throughout, by this method, than to produce a casting apparently sound, but which is internally defective. If nails are used in re-entrant angles or bosses, they should preferably be the ordinary carpenter's tinned nail. If moulder's sprigs are used they should be dipped into spirits of salts before use, as there is a grave risk of gas, formed from the rust on the sprigs, producing a gas hole in the casting. Moulds containing these treated sprigs should be closed as short a time as possible before casting, as the moisture from the mould tends to condense on them and produce a similar effect.

Effect of Mould Gases.

The last subject for consideration is the effect of mould and metal gases. It is well known that metals tend to hold gases in solution and to evolve them on solidifying. Fletcher considers this as the main cause of all drawing, but in the case of irons which draw through being too soft this is not thought to be the case. The examination of a great many draw-holes of this type shows little evidence of the presence of gas, or, at any rate, of gas under pressure, and the draw-holes are usually dark and rough inside. Where the draw is due to gas, the hole is usually smooth inside, and has a light-bluish skin; this is observable in the draw-holes in semi-steel, and in cold-run casting.

Fig. 17 shows such a typical draw in a cold-run semi-steel casting, wherein the slight sinking in the top face can be noted. Mould gases will often move a draw or spongy area to another place. If the pressure of mould gases is exceptional in any part of the mould, then the draw will often go to that place rather than to its normal position. Fig. 18 shows this effect. The casting, which is only 5 in. × $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in., tends to draw inside the deep slot on the right, which is horizontal in the mould. But in this case, excessively hard ramming or a patch of wet sand has caused the draw to go to the bottom of the casting as shown. There was no sign of draw in the slot.

Another example is shown in Fig. 19, which is the centre portion of a cam casting about 10 in. diameter and weighing 16 lb. In this case the draw appears above the rather narrow projection of sand seen in the left-hand bottom corner of the broken casting. The nature of the draw is seen in the right-hand specimen. This casting normally gives no trouble, but a change of conditions in the projecting sand, either hard ramming or excess moisture, causes this spongy area. It is a recognised fact that slight draws in awkward corners of a mould can be overcome by the use of a little raw red sand. The explanation of this seems to be that the uncrushed grains of the red sand allow of a more free passage of the mould gases, and thus prevent excess gas pressure at this point. Reverting to Fig. 5, this casting can normally be made free from drawing by the method indicated, but if the composition of the iron is unsuitable, either raw red sand or a nail is used at the point where the drawing occurs, which is just to right of the central boss.

Conclusion.

The cause of drawing in grey-iron castings is that the expansion due to formation of graphite is practically all absorbed in expanding the outer shell of the casting, and the remaining liquid shrinks. *The amount of drawing* in a casting is governed by the following, the conditions stated being those which tend to reduce the amount of drawing:—(*a*) The composition of the metal (low silicon, low phosphorus, high manganese and medium total carbon are ameliorative); (*b*) rapid uniform freezing of the metal as governed by the mould size and conditions; (*c*) the feeding of fresh liquid metal into the casting by means of runners and risers, and the increased efficiency of these due to high casting temperatures; and (*d*) the provision of means for the ready escape of the mould gases.

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Wales and Monmouth Branch.

ELECTRO-METALLURGY OF STEEL FOR FOUNDRY USE.

By R. J. Richardson (Member).

Historical.

Credit is due to Sir Wm. Siemens for introducing the first experimental electric furnace when he melted steel in 1882, using a crucible having an electrode protruding through the cover or lid as shown in Fig. 1. The hearth or bottom of the crucible had a metallic pole passing through it, on which the charge was placed. The arc was struck from the hanging electrode on to the charge which conducted the current to the bottom pole. This is the system employed in direct arc type furnaces of the present day.

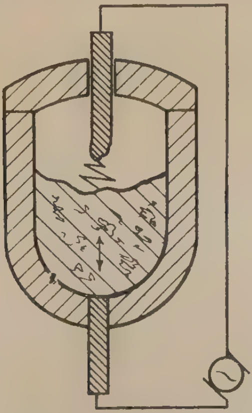


Fig. 1. — Siemens Direct Arc.

Siemens also used an indirect furnace about the same time; this is shown in Fig. 2. Here the crucible containing the charge had two horizontal electrodes passing through the side walls, above the level of the charge and arced in a similar manner to the common arc-lamp, heat being given to the charge by radiation from the electrodes and by reflection from the roof and walls. This system is also employed in modern furnaces. The diagrams only show the experimental types, and are not necessarily true descriptions of modern developments.

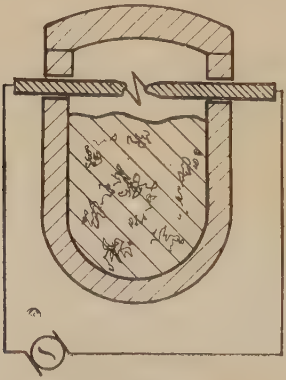


FIG. 2.—SIEMENS INDIRECT ARC.

In 1899, following a period during which no advances seem to have been made, Stassano used an indirect furnace, Fig. 3, which is similar to an iron foundry cupola having electrodes horizontally protruding into the furnace in the place where we find our tuyeres. This was used for direct reduction of iron ore, and after modifications was attended with a fair amount of success.

During this time Dr. Heroult was experimenting with a furnace for the production of steel from scrap and pig-iron, trying to follow, as far as he could, the standard methods of the basic open hearth furnace, and avoided carbon contamination by using a slag covering and also by the use of a non-carbonaceous lining.

In 1899 Heroult was employing a single-phase bottom electrode direct arc type furnace similar to that of Siemens, but was experiencing trouble with carbon absorption from the bottom electrode, so he replaced it by another electrode in the roof and formed the first furnace with two arcs in series. Fig. 4 shows the furnace and the manner in which the electrodes were held.

This type was found very successful, enabling him to make low-carbon steel, and Heroult next turned to find methods of refining of steel in his furnace. The single-phase furnace was altered by Heroult to a three-phase furnace, and was very much the same as used to-day.

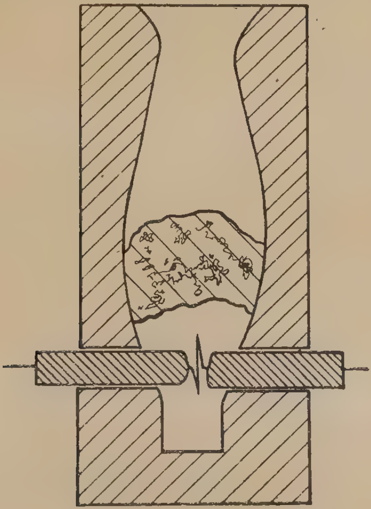


FIG. 3.—STASSANO.

In 1905 Girod made a steel furnace for use with a bottom electrode, having graphite poles embedded in a non-conductive hearth; this was fairly successful, being succeeded by a conductive hearth built of a refractory with a carbonaceous binder, as shown in Fig. 5.

In 1908 the Electro-Metals furnace was introduced, using a two-phase current. Two electrodes protruded through the roof, a common neutral return conductor connecting the conductive hearth to the neutral point of the two phases.

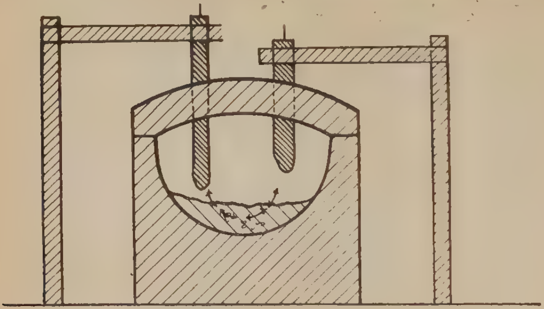


Fig. 4.—Heroult 2-Phase in Series.

Stobie modified the Electro-Metals type three years later by using two return conductors (one for each phase) instead of the common return, the carbon electrodes being diagonally opposed to its corresponding top electrode instead of directly below it, as shown in Fig. 7.

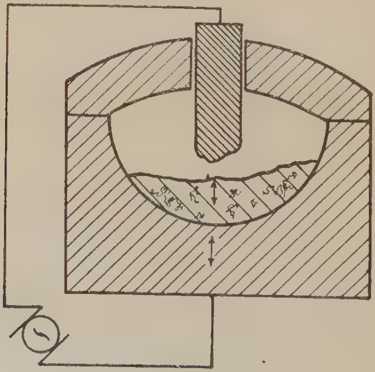


Fig. 5.—Girod.

Fig. 8 shows a Greaves-Etchells furnace which is an example of a bottom conductive hearth furnace of modern design, and consists of a three-phase supply, two phases being connected to two upper electrodes, whilst the third phase is connected to the conductive hearth which acts as a large electrode.

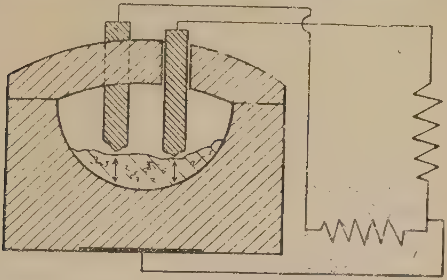


FIG. 6.—ELECTRO-METALS.

The development of Electric steel manufacture was very slow until 1915, when only 213 furnaces were working in the whole world, whilst in 1920 it is estimated that 1,390 were working, or an increase of 650 per cent. in five years. As far as England is concerned, the conditions here in 1915

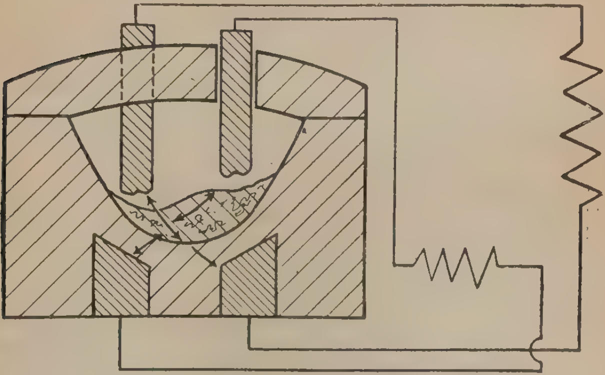


FIG. 7.—STOBIE.

were such that the stocks of heavy steel turnings were high and high-grade raw materials and scrap were running short, yet the demand for high-grade steel was abnormal. These conditions presented ideal opportunities for exploiting the electric furnace, and once started, it was proved to have economic advantages.

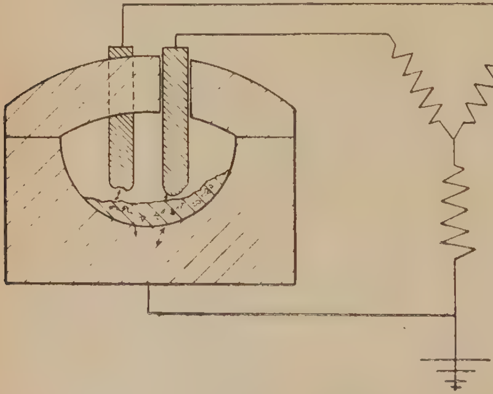


FIG. 8.—GREAVES-ETCHELLS.

A Modern Furnace.

The methods of melting and refining in different furnaces are very similar. A Heroult direct arc three-phase furnace, taking a 2-ton unit as a basis for dimensions and times, can be described as consisting of a shell casing of 1-in. plate, shaped in the form of a straight-sided cylinder closed at the bottom, which is curved. The whole is riveted to two steel castings which are curved, and act as a track on which the whole tilts on four rollers.

The diameter is about 8 ft., and height from the bottom of shell to the level of sills is 32 in. A 5-h.p. motor serves to tilt the furnace by rotating a screw-thread through gearing. The charging doors are on each side and the spout in front, whilst at the back are found the electrode controls. Hand control wheels acting through racks and pinions raise or lower the electrode holders and bus-bars, together with the water-cooling pipes.

The holders are hinged for gripping or releasing the electrodes, and are usually phosphor bronze of high conductivity. The electrodes are either 6 in. dia. graphite or 14 in. dia. amorphous carbon. The electrodes protrude through three holes in the brick roof, and water coolers rest on the roof, cooling any gases passing through those port holes, avoiding undue loss of electrodes through burning.

The roof is a plain ring of 1-in. plate, the same diameter as the furnace, and about 14 in. deep, having a 2-in. by 2-in. angle riveted to the bottom of the ring projecting inwards; this ring and angle carry the specially formed skewback bricks on which the arched brick roof is built. This bricking is done on a template, and the holes for the electrodes are thereby accurate in shape and position.

The electrical gear consists of a set of star-delta connected transformers (situated immediately behind the furnace) of 750-kw. capacity stepping down from 11,000 to 103 or 78 volts. The voltage is changed by means of an oil switch which is interlocked with the main or tripping switch. The main switch is provided with a tripping arrangement; a time trip is also introduced by means of fuses. Flexible cables are taken direct from the secondary terminals of the transformers to the clamps on the 'bus-bars of the furnace. Ammeters denote the current passing the electrodes, and three lamps are connected between the cables, and a common point such as the furnace shell. The lamps and ammeters are mounted above the electrode control gear to be easily visible to the operators. The light from any lamp is dependent on the voltage between its electrode and the bath of metal indicates when one electrode is shorting with the charge. For instance, assume two electrodes are raised off the scrap and the other is touching the scrap; no current will be shown on the ammeter since no circuit is completed, unless two electrodes are "arcing" and there is danger of bringing the lower electrode down further, which would result in its breaking, with the usual loss of time and money. With the lamp in to show voltage, the shorted electrode would drop the voltage and the lamp would give little or no light. Similarly, this lamp is particularly useful when scrap is falling from the sides of the furnace, and indicates on which electrode it is falling, whereas the ammeter only shows the amount of current passing, dependent on the two electrodes carrying that particular phase. A voltmeter is used indicating line voltage, or by plugging connections the arc voltage can be indicated.

Furnace Linings.

Either acid or basic lining is suitable for Heroult type furnaces, and, firstly, a basic lining will be described. A single course of fireclay covers the bottom of the furnace; a magnesite brick wall is built around the inside of the shell to the height of two courses above the sills. The binder used is a mixture of tar and pitch and ground magnesite, and the spaces left behind the 9-in. wall are rammed with old brick and ground magnesite. Above the magnesite wall is built a silica brick wall bonded with a wash of ganister and water; perfectly shaped, flat, even bricks are essential to good life, and should require a minimum of facing material. The brickwork is then thoroughly dried by fires.

The hearth is formed of either magnesite or dolomite, the latter being favoured here owing to cost. The dolomite used must be perfectly dry and crushed to pass through a ¾-in. sieve, having enough dust and small to fill all spaces between the large-sized lumps. It is then heated to about 100 deg. C. on a hotplate, and mixed with the requisite amount of tar and pitch to result in an adhesive mixture without excess of tar. This is commonly called "Black Basic."

It is rammed immediately with hot rammers in layers of 1½ to 2 in., until the required thickness of the bottom is reached—in this case 14 in.—and finally the banks are rammed and shaped to the form of a bowl. There must be no stoppage during the operation, or trouble will arise through a layer not having thoroughly united to the one below it, in which case it will rise when a heat is in progress.

Acid Linings.

Acid linings are built in a similar manner. Silica bricks are used throughout, except for the fireclay base. The hearth is formed with twelve parts silica sand to one of fireclay, and rammed in the same way as the basic lining. Before using any hearth it must be slowly baked. Silica bricks need to have their moisture removed carefully, and to be heated slowly to avoid unequal expansion and thereby minimising spalling.

Pieces of old electrodes or good foundry coke are placed over the hearth, and the current switched on a few minutes at a time, and heated by the arcs to bring the furnace to a dull red heat in about 10 hrs.; then the current is increased to bring the furnace to about 1,000 deg. C., until all the tar is burned out, which will show itself by the lack of black smoke previously emitted from cracks between the hearth and brickwork. Finally, the hearth is heated white hot at full load for from half to one hour. The carbon or coke is withdrawn and scrap is charged. The furnace is then ready for use.

Basic Operation of Electric Furnaces.

The manner in which basic steel is made differs very little for different types of electric furnaces, so an effort will be made to describe a basic heat as conducted in a Heroult 2-ton 3-phase furnace.

The charge consists mainly of steel turnings which should be free from oil, nickel, or other impurity, and should be as clean as possible. If siliceous matter is present in excess, it will cut the hearth. With the turnings are also charged mixed small scrap and feeding heads and gits returned from the dressing sheds.

At the conclusion of a heat, the hearth having been repaired, a few shovels of lime, and possibly a little iron scale or ore, are thrown in and the larger pieces of the charge are placed on the hearth and intermixed with turnings. Then the lighter scrap and remainder of the turnings are thrown in and heaped up as high as possible in order to protect the side walls from the action of the heat given off by the arcs. The furnace is now ready for operation either immediately or within two days, without undue risk of the hearth deteriorating.

Before starting, make sure the electrodes are above the scrap, then switch in on the higher voltage, in this case 103. On lowering the electrodes the current passes between the electrodes and the scrap, forming an arc, and locally melts a few drops of metal, and the electrodes have to be again lowered; the melted metal trickles down to the hearth. By continuing this local melting and lowering of the electrodes, three holes are bored in the charge, until three pools of metal and slag are formed on the hearth and the load becomes quite steady. This takes from ¼ to ½ an hr., varying with the kind of scrap used. This is what is generally called "getting a bath." The arcs now pass to both the bath and the sides of the holes, the molten metal increasing the depth of the bath, necessitating the electrodes being raised to keep the required amperage, until they finally come back up to about 6 in. below the level of the sills. The centre of the scrap that is, the portion between the three holes formed by the electrodes, will gradually fall into the pools of metal. As soon as this falls, it is time to charge any further scrap left over from the first charge, and melting proceeds.

The two things to avoid are "top heat" (Fig. 9) and "bridging" (Fig. 10). The cause of top heat is using scrap which lies too closely, such as rivets and punchings, which on melting will not allow the metal to run right down to the hearth, so the pools are formed on top of the scrap (shown) instead of on the hearth. The major portion of the scrap had to be melted by radiation and the silica walls and roof will suffer through the extra exposure to the hot metal and arcs, and current consumption is excessively high.

"Bridging" occurs in too open a charge, or a charge of long strips, which will tend to weld themselves together. The bath is successfully formed, but it does not increase in depth, so spreads over the hearth and is rapidly superheated to such an extent that the hearth is burnt, the remainder of the scrap forming an arch or bridge over this pool, as shown in Fig. 10.

Assuming no delays, as mentioned, having taken place, melting is continued until a completely-molten bath is obtained, when any small portions of scrap adhering to the hearth above the metal level are raked into the bath. The metal is now super-heated and the slag being correct, the switch is opened and the slag

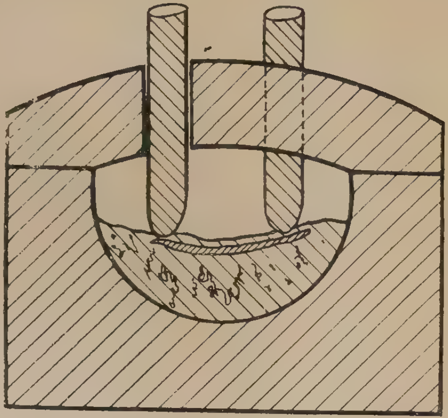


Fig. 9.—Melting Conditions Giving Top Heat.

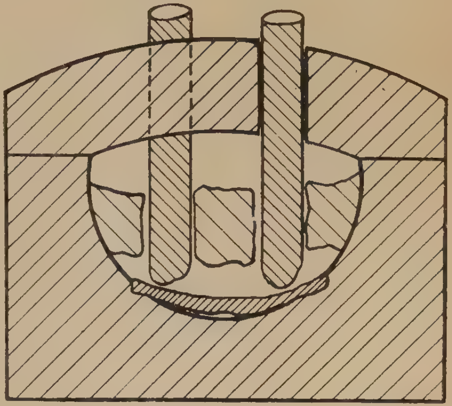


Fig. 10.—Melting Conditions Resulting in Bridging.

removed by tilting the furnace and raking off.

The reactions of this slag are somewhat similar to those of an open-hearth basic slag. The slag will contain an excess of oxide in the form of rust and added iron ore or scale. Lime is also present in excess.

Removal of the Elements.

The carbon present combines with iron oxide and forms iron and carbon monoxide. The CO rising through the slag gives the appearance of boiling, by which name it is known. As the carbon is eliminated, the melting point rises and also the reaction, being endothermic, this elimination is restricted in other methods of melting by the fuels, but owing to no such restriction except the refractories failing in electric furnaces, the elimination of carbon can be, and is, carried to a far greater extent.

If the average carbon content of the scrap is consistent, the requisite amount of oxides is added before melting, and no delay is experienced. During melting, should the carbon be high, further oxides are added. Slag tests are taken periodically, a brown streak denoting lack of oxide, and if enough oxide is present, the flames of CO are noted, denoting presence of C in the bath. A bath test is taken as a final check for the presence of carbon.

BASIC PROCESS OXIDISING—SLAG EQUATIONS.

1. $Fe_2O_3 + 3C = 2Fe + 3CO$
2. $2Fe_3P + 8FeO = (FeO)_3P_2O_5 + 11Fe$
3. $(FeO)_3P_2O_5 + 4CaO = (CaO)_4P_2O_5 + 3FeO$
4. $2FeO + Si = SiO_2 + 2Fe$
5. $FeO + Mn = MnO + Fe$
6. $3FeO + Mn + Si = MnSiO_3 + 3Fe$

Phosphorus is present as iron phosphide Fe_3P, and on combining with the iron oxide forms the pentoxide which, being acid, combines with and is fixed by lime, resulting in a stable calcium phosphate.

The elimination of phosphorus is slow until the C, Mn and Si are boiled down to fairly low figures, when the phosphorus rapidly combines with the lime.

The reasons for the rapid phosphorus elimination are, the high temperature near the arcs, accelerating slag reactions, and silicon and carbon can be safely reduced to a very low figure, since the deoxidising slag which follows will rectify any wild metal.

Manganese and Silicon present no difficulty, being oxidised to MnO and SiO_2, either separately or as a silicate of manganese.

The composition of the bath at the completion of this slag will be as follows:—C.C., 0.03 to 0.06; P, 0.01 to 0.02; Si, trace; and Mn, trace to 0.3 per cent.

The slag should be a dull matt colour, having no glassy parts, and on fracture, after cooling, should be stone grey in colour and will have the following analysis:—Silica (SiO_2), 10 to 15; manganous oxide (MnO), 7 to 10; iron oxide (FeO), 10 to 15; lime (CaO), 45 to 60; magnesia (MgO), 4 to 8; and phosphorus pentoxide (P_2O_5), 2 to 4 per cent.

The Refining Slag.

The furnace is skimmed free from any oxidising slag and returned to the horizontal position, and is ready for carburising. The amount to be added is calculated and added in the form of anthracite duff, which has been previously sieved to free it from dust and dirt. Care must be taken not to add too much at a time owing to the reaction that takes place on combining with the metal. Part of the anthracite is burnt, part reduces the remaining portions of oxidising slag, and the remainder combines with the steel.

About 10 lb. of FeSi in dust form is added, with half a cwt. lime and a few lb. of fluor spar for slag forming. The voltage is changed to 78 volts and the current switched on. When the lime and spar are fused, anthracite dust is added, about two shovels full will generally suffice to form a good slag. The slag formed is peculiar to electric furnaces alone, and is reducing and deoxidising, the anthracite forming this highly-reducing atmosphere.

As the temperature rises the slag forms, turning to a brown colour, then to a yellow or greyishwhite colour, and as deoxidising begins, foaming takes place, first round the electrodes and then spreading all over the bath. A sample of slag taken on a rod and quenched in water will give a distinct odour of acetylene, showing presence of calcium carbide. This slag will be very conductive (electrically), and will not radiate a great deal of heat to the refractories.

The actions under this slag are deoxidising and desulphurising. It will act as perfectly neutral covering, enabling the metal to be held at any time without any chemical change except S reduction. It will contain such a small amount of oxides that when any ferro-alloys are added no allowance need be made for oxidation loss, thereby enabling very exact results to be obtained.

The reactions take place as follows:—

When the slag is fusing it picks up FeO, which is acted on by the anthracite liberating the iron to the bath, and the CO evolved passes out.

The sulphur is present as FeS (or MnS), and combines with the lime and anthracite, forming iron, calcium sulphide and CO. If oxides are present in the slag, the calcium sulphide combines with FeP, reforming FeS and CaO. Should no such oxides be present, the CaS remains in the slag, and, in presence of anthracite, calcium carbide is formed, denoting rapid elimination of sulphur and freedom from oxides. The CaC_2 rapidly combines with any oxides dissolved. When Mn is added in the form of ferro-manganese or spiegel, it will thoroughly scour the whole of the metal, freeing it from all oxygen. The MnO rises to the slag and is acted on by the reducing atmosphere, and the Mn returns to the bath. This

Basic Process Reducing—Slag Equations.

7. $FeO + C = CO + Fe$
8. $FeS + CaO + C = CaS + Fe + CO$
9. $CaS + FeO = FeS + CaO$
10. $3FeS + 4CaO + 6C = CaC_2 + 3Fe + 3CaS + 4CO$
11. $CaC_2 + 3FeO = 3Fe + 2CO + CaO$
12. $Mn + FeO = MnO + Fe$
13. $MnO + C = CO + Mn$

proceeds until all the oxygen is brought into contact with and eliminated by the slag.

The slag will have a composition somewhere within the following limits:—CaC_2, 3.0 to 7.0; CaF_2, 0.18 to 0.22; CaS, 0.5 to 0.8; CaO, 45.0 to 55.0; Al_2O_3, 2.0 to 4.0; MgO, 2.0 to 3.0, and C, 0.8 to 1.5 per cent.

The only trouble experienced with this slag is that caused by dripping or spalling silica bricks from the roof or side walls. As soon as the slag is correct, a bath sample of the metal is sent to the laboratory and analysed and corrective additions of FeMn alloys calculated and added. The bottom-pouring ladle is prepared and placed in the pit. Samples of metal are periodically taken and Si content estimated, the Si being increased by ferro-silicon.

The temperature of the metal is estimated by immersing a rod of standard size, say ½ in., in the metal for a certain time and noting the reduction in the size of the rod. The slag temperature and analysis being correct, the switch is opened and electrodes raised, then the furnace is tilted over, delivering the metal into the ladle in the pit. The furnace is returned to its horizontal position and the hearth repaired and scrap charged for the next heat.

The average times taken on intermittent running of, say, one heat per day are:—Melting down and boiling under first slag, 1½ to 1¾ hrs.; slagging off and carburising, 7 to 10 mins., refining under reducing slag, analysis, making additions, and raising temperature, 35 to 40 mins. No additions except half a pound of Al per ton of metal are used in or added to the ladle.

Acid Practice.

The acid process though not used so much in this country might be of interest. The hearth was dealt with in the description of linings, other structural and electrical features are similar to the basic, excepting the voltages used, which are higher owing to the lower conductivity of acid slags. No phosphorus is removed and sulphur elimination is almost negligible, so the charge must be low in these elements. The scrap must be carefully selected, and if possible mixed to give a desired average content of carbon, thus avoiding its total elimination when melting down. Rust and dirt cause the most serious detrimental conditions if present in excess.

Melting proceeds in the same way as in the basic furnace. The slag is formed from the oxides charged as rust and dirt, also silica from the hearth. The bath is formed and oxidation takes place, eliminating C, Mn and Si. When all the metal is melted, slag and metal tests are taken. If the slag is black and thin or glassy, it denotes a highly oxidising condition, whilst a slag lacking in oxides will appear pasty or thick, and will be light green in colour. The oxidation of C, Mn and Si gradually uses up all the available oxides in the slag until it becomes quite inactive and no further elimination takes place.

If the scrap has been ideally mixed, the desired amount of C will now be present; unfortunately, this is seldom the case. It is interesting to note that in practice with ordinary scrap the presence of these three elements is in direct proportion to one another or nearly so, and if one is judged the others may be estimated fairly accurately.

Should the results be low, by the time the slag has become inactive the metal will be wild, and unless a reducing slag is going to be used, it will be very difficult to produce a good sound steel. For this reason it is advisable so to mix the scrap that it will melt down to high content of C and Si, then by the addition of further oxides in the form of ore in small quantities at a time, the desired analysis is gradually obtained. Bend tests are taken and the carbon thereby judged, and when nearing the desired figure a sample is analysed and the ferro-alloys calculated, allowance being made for loss through oxidation; this varies under different conditions from 7 to 15 per cent.

If the slag is light green in colour and pasty, the temperature is raised sufficiently high for pouring, taking care the slag does not alter, since it must be thin enough to pour and yet be thick enough to be held back in the ladle. A few minutes before pouring the Mn additions are made in the furnace. Ferro-silicon is either added at the same time or is placed in the bottom of the ladle.

Reducing Acid Conditions.

It is common practice in America to use a reducing slag in acid furnaces. Melting proceeds as before until a bath of low C, Mn and Si content is reached, and the temperature is still low. The slag is full of oxides, and to satisfy them fresh slag is added in the form of silica sand. In about 5 minutes dense white fumes are emitted, changing to a yellowish-white colour, denoting that reduction is taking place; the metal will still have a fair amount of oxides present, and these will gradually be absorbed by the reducing slag. The slag should be dark green in colour and fairly thick. If too thin and green, more sand must be added, and if black, a dusting of anthracite will re-start the reduction.

Metal tests are now taken for soundness, and as the metal becomes deoxidised, the slag turns to a greenish-yellow colour and will be sticky. This is most noticeable on taking a spoon sample, when long strings of slag will hang from the spoon. The metal will now be absolutely freed from oxides, and the temperature is raised and additions made.

Sometimes, through excess of silica, the slag turns too thick and arcing is irregular; the silicon being rapidly reduced passes into the metal. To prevent this, lime is added. The necessary additions are made, carbon and manganese are increased with pig and FeMn or spiegel.

Silicon additions can be made in three ways:—(1) By ladle additions of FeSi; (2) by FeSi in the bath just before tapping, or (3) by reduction, such as was described, under a very thick slag This is accelerated by anthracite dusting.

This reduction condition, whilst presenting an ideal method, must be under a very careful and skilled operator, since in a very short time the silicon content can change from that of a wild steel to the other extreme; the rate of silicon pick-up can only be obtained by carefully conducting heats under similar conditions, and then using the figure derived for controlling future heats. If satisfactory silicon results be obtained by this method the metal undoubtedly is as good as that made by the basic process.

The principal reactions in acid practice are as follows:—C, Mn and Si are oxidised to FeO, MnO and SiO_2, as in basic practice. The phosphorus is oxidised to $(FeO)_3P_2O_5$, but in the absence of the lime base it turns to the metal. The stable slag is formed by the combination of the oxides and the silica. When the slag becomes very thick or heavy, reduction may take place. This is accelerated by the addition of anthracite dust, the nascent silicon first deoxidising the metal and then combining with it and raising the silicon content of the bath. The anthracite also reduces any oxide formed evolving CO. When lime is added it prevents this reduction even in the presence of free carbon showing the silica having a higher affinity for lime than for reduction.

ACID SLAG EQUATIONS.

14. $FeO + MnO + 2SiO_2 = FeSiO_3 + MnSiO_3$
15. $SiO_2 + 2Fe = 2FeO + Si$
16. $SiO_2 + 2C = 2CO + Si$
17. $FeO + C = Fe + CO$
18. $MnO + C = Mn + CO$
19. $SiO_2 + 2C + CaO = CaSiO_3 + 2C$
20. $SiO_2 + 2Fe + CaO = CaSiO_3 + 2Fe$

Time of Heat.

The time taken with a reducing slag is very much the same as in the basic process. When only an oxidising slag is used, about half an hour is saved.

Acid *versus* Basic Electric Steel.

Unless otherwise mentioned, the ordinary acid practice with no reduction is referred to. The plant used is identically the same, the acid lining having the advantage, as far as lining and running costs are concerned. The scrap for the basic process is both cheaper, needs less selection and supplies are plentiful, whilst with acid the difficulty of obtaining the proper scrap in this country has resulted in more than one furnace reverting to the basic process.

The actual conversion costs including current, labour and electrodes are fairly proportional to the time taken under load, so here the acid slag has the advantage, the difference between conversion costs of steel made under basic and acid reducing slags is very small. The units consumed per ton of metal on continuous running are:—

Basic 650 to 720 and *acid* 550 to 650 per ton, and for intermittent running of, say, one heat per day, are:—

Basic 870 to 970 and *acid* 800 to 900 per ton.

When considering these figures, it must be remembered that foundry requirements differ seriously, particularly in the temperature for pouring. For instance, some heats will be poured into only three or four moulds, whilst the next might be used for 80 separate moulds, or more. As many as 105 separate moulds have been poured, some of which contained six castings, with 30 cwt. of metal, in which case extra time and current were taken to get the required amount of superheat.

The metal produced is not very different, the basic steel is regularly made to within limits of 0.01 to 0.02 per cent. of C. and Mn and the acid has limits of 0.03 to 0.04 per cent.

The chief disadvantage of acid steel which is only boiled down and the alloys added with no reducing slag actions, is the presence of occluded or dissolved oxides, which together with the higher sulphur cause tearing of the castings during contraction and possibly the loss of mechanical strength.

The basic and *reducing* acid steel furnaces are regularly producing the best steel obtainable, and physical tests show higher tensiles for an equivalent C content of other types with increased ductility.

Table I shows a few test results taken at random:

In conclusion, a brief comparison between electric basic and converter steels is given, without mentioning any actual figures. Electric conversion costs are higher in fuel refractories and electrodes whilst the converter uses more expensive scrap and has a higher melting loss, but has a fair advantage generally. Converter steel often has dissolved oxides present, although these are not visible to the naked eye, but can be seen under the microscope; the sulphur is also higher and together, they are the cause of quite a number of

TABLE I.—*Test Results on Electric Steel Castings.*

C.	M.	P.	S.	Si.	Tensile Str. Tons per sq. in.	Elongation. Per cent.	R.A. Per cent.	Cold Bend. Degrees.
0.22	0.62	0.029	0.032	0.26	30.5	35.0	51.0	190 unbroken.
0.24	0.63	0.036	0.017	0.30	34.4	26.5	33.0	170 broken.
0.30	0.72	0.028	0.019	0.30	35.0	33.0	43.0	180 broken, with flaw.
0.37	0.75	0.032	0.025	0.32	42.0	13.0	22.0	140 broken, contraction, draw.

the castings being scrapped through pulling or tearing. These troubles, fortunately, are almost unknown with basic electric steel. They are both suitable for light thin sections, but the restricted temperature of converter steel is accountable for a few short-run wasters. Both are under very good chemical control, the elements Mn and Si vary in converter steel, through the loss by oxidation not being consistent.

The future of electric steel depends on (1) the regularity with which it produces high-quality castings, definitely sound and free from pulling, both visible and internal, to the most rigid of specifications; (2) the thin sections which can be cast without misruns, and (3) the fact that the percentage of rejected castings from all sources is very much lower than that of any other process.

For those reasons and the present trend of modern engineering design calling for the very best and purest articles with little doubt as to failures in use, electric steel will in the future more than hold its own and become universally in demand.

Lancashire Branch.

ELECTRIC MELTING.

By H. S Primrose, A.M.I.Mech.E (Member).

Introduction.

A few years ago the electric furnace was not regarded seriously by either ferrous or non-ferrous foundrymen, but during recent years great progress has been made, and the advantages of electric melting have been realised to some extent.

The war was responsible for bringing the electric furnace for steel making into prominence very much more quickly than would have been the case under normal conditions, as this type of furnace was particularly suitable for the production of special alloys, and such alloys were in great demand. There was also a large amount of steel scrap available during the war, which was ideal material for electric-furnace practice.

During the last three or four years, the electric furnace for melting brass to be rolled and extruded has been adopted very largely, and it is not generally known that about two-thirds of the world's supply of yellow brass for rolling mills is now being made in one type of electric furnace alone.

Types of Furnaces.

Although there are many different types of electric furnaces now in use for both ferrous and non-ferrous melting, it is only proposed, in this Paper, to deal with three types of electric furnaces for melting, which have proved to be very successful in operation. These types are:—(1) Héroult furnaces for ordinary and alloy steels, (2) Ajax-Wyatt furnaces for melting brass, (3) Ajax-Northrup furnaces for melting special alloy steels, high-copper alloys, nickel-copper alloys, pure metals and high-melting-point metals.

Héroult Furnaces.

In his Paper to the Iron and Steel Institute in September, 1910, on electric-steel refining, Campbell indicated what was afterwards to become an accomplished fact—"that the electric furnace is especially suitable, and will be largely adopted, for any class of work in which raw materials of a high degree of purity are now used."

In the Héroult electric furnace almost any degree of refining of the steel can be effected, and the removal of sulphur, phosphorus and oxygen is especially easy. This is probably due to the following three causes:—(1) The intense heating of the slag, which is the place at which the refining takes place. Owing to this high temperature and the extreme fluidity of the slag, the rate of the refining reaction is very great, because the velocity of reaction rises very quickly for high temperatures, and not in direct proportion to the temperature; (2) the extremely basic slag that can be kept in a very fluid state, and the calcium carbide formed by the action of the arc on the calcareous slag, are especially advantageous for desulphurisation; and (3) the violent motion of the steel which results from the convection currents produced in the bath, due to the two intensely hot areas caused by the arcs below the electrodes, increases the volume of steel exposed to the hot and fluid slag area, and hence the rate of refining.

Types of Héroult Furnaces.

The Héroult electric furnaces are of the type in which the current passes down one electrode through the slag to the metal and thence back through the slag again to a second electrode (taking the case of the single phase furnace) no bottom electrode being used. The size of the furnace depends on the requirements, and the following particulars are of sizes which are now in use.

10-*cwt. Furnace.*—This size of furnace is specially suitable for making high-speed steel or very light castings. The electrodes are graphite, of $5\frac{1}{8}$ in. diameter. The power used with the furnace varies from 200 to 400 k.v.a. With the latter a heat can be made in from $1\frac{1}{4}$ to $1\frac{1}{2}$ hours. The furnace is arranged so that the body can be removed and replaced by a spare body already lined and kept in readiness, so that no delay is necessary for repairs.

1½- *to* 2-*ton Furnace.*—A furnace of this size is suitable for making high-speed and other tool steels, special steels of which comparatively small quantities are required, and small castings. It is of the three-phase type with three electrodes, and the electrodes are of graphite, usually of 6 in. diameter. The power used with this furnace varies from 450 to 600 k.v.a., and the number of heats per day of 24 hours varies from 5 to 7, according to the power available, the degree of refining, etc.

3- *to* 3½-*ton Furnace.*—This furnace is suitable for making alloy steels and carbon steels, and for steel foundries where a fair proportion of the castings are of medium weight, say, one cwt. or more. High-speed steel is also being made in large quantities in furnaces of this capacity, but many firms do not care to make such large heats of tungsten steels. The transformer capacity varies from 600 to 900 k.v.a., and the output is from four to five heats per day. With transformers of 600 k.v.a. capacity an average of about 80 tons of ingots per week has been maintained over prolonged periods, and, with transformers of more power, output would be correspondingly increased.

For this size of furnace many steel makers prefer to use amorphous carbon electrodes of 14 in. or 16 in. diameter. If graphite electrodes are used they should be of 7 in. or 8 in. diameter. The use of carbon or graphite electrodes depends largely on the supply available and the relative cost. Graphite electrodes are more expensive per ton, but the consumption is only about half that of carbon electrodes. Generally carbon electrodes are preferred for technical reasons, but, on the other hand, graphite electrodes are easier to handle.

6- *to* 7-*ton Furnace.*—This size of furnace is most widely used in both England and in the United States. It is especially suitable where considerable quantities of alloy or carbon steels are required. For this size of furnace carbon electrodes of 18 to 20 in. diameter are recommended, and, if graphite electrodes are used, they should be 9 to 10 in. diameter.

10- *to* 12-*ton Furnace.*—This furnace is of a different design from the other furnaces described, the charging door being placed at the back of the furnace instead of at the sides. Furnaces of this type are being used for making alloy and carbon steels, and also for refining molten steel from open-hearth furnaces. These furnaces are especially useful where large ingots are required. The power varies from 1,800 to 2,400 k.v.a., and, when melting cold scrap, about four heats a day can be made, and, with hot metal, about ten heats can be refined. Furnaces of 15, 25 and 35 tons capacity are also in operation in the United States and on the Continent.

The Héroult furnace resembles most nearly a tilting open-hearth furnace. The arched roof is pierced by two or three electrodes, and the furnace is heated by electric arcs—one between each electrode, and the slag or melted metal beneath it. The Héroult furnaces were first built for single-phase currents, but to-day they are nearly all being operated by poly-phase currents, usually 3-phase circuit of any standard periodicity. All 3-phase types of Héroult furnaces are designed with a circular hearth over which three electrodes are arranged at the corners of an equilateral triangle. In one case a 15-ton furnace is being operated by a 3-phase, 25-cycle current, with a Delta connection, at 100 volts. Under these conditions, the current per phase rises to 12,000 ampères. The electrodes are automatically regulated, and the current is taken from a high-tension circuit and stepped down by means of three 750 or 1,000 kilowatt transformers. Accordingly, a 15-ton furnace takes $12,000 \times 100 \times 1.73 = 2,076$ k.v.a., but as the power factor is between 0.8 and 0.9, it consumes actually $2,076 \times 0.85 = 1,760$ or say 1,800 kw. A low tapping of about 75 volts is used for finishing, and the capacity of the transformers is reduced in proportion. The output of such a furnace, when melting cold scrap continuously for 5½ days per week, is approximately 5 tons a year for each k.v.a. of transformer capacity, that is, a 600 k.v.a. furnace melts 3,000 tons a year.

Electrodes.

Either amorphous-carbon or graphite electrodes can be used for these furnaces. The conductivity of the latter is about four times that of the amorphous electrodes, so that the electrodes of only $\frac{1}{2}$ in. diameter may be used. The chief advantage of the graphite electrode is its small size and the resultant ease of handling. On the other hand, from the metallurgical point of view, a large electrode is advantageous, as the arc is less localised and a larger area is directly heated. With furnaces of 2 tons capacity, or less, graphite electrodes are usually employed, as the amorphous electrode takes up rather a large proportion of the roof space, and the comparatively small tonnage required can usually be obtained.

The question of relative cost is quite an item, and, unless graphite electrodes are greatly reduced in price, this type of electrode will be unable to compete with the amorphous.

With regard to electrode holders, it may be said that water coolers are placed round the electrodes on the roof and the holders are also water cooled. The holders are hinged, and a great deal of experimental work has been done to obtain a suitable material for their manufacture.

The Soderberg Electrode.

Within recent years a new type of electrode has been put forward known as the "Soderberg Continuous Self-Baking Electrode," and this is an important improvement in the manufacture of electrodes which results in a substantial reduction in the cost of melting steel by electricity, and eliminates the trouble of broken electrodes with its resulting loss and trouble to the steelmaker. The electrode consists of a light steel tube built up with riveted and welded steel sheets arranged so as to provide projecting fins which penetrate the carbon paste which is rammed into the tubes. These fins reinforce the electrode and prevent breakage. The cost of the electrode is about half the cost of best quality amorphous electrodes, and the consumption is slightly less, because the steel plate protects the carbon from oxidation when it enters the roof. By the use of these electrodes faster melting and more uniform heating is obtained, because this electrode does not become pointed and covers a larger area of the bath. Due to this, the roof and sides of the furnace last longer, and the steel is not burnt or oxidised by intense local heating by arcs, which expose and blow aside the slag. This type of electrode being slightly plastic, it takes the exact shape of the electrode holder and so ensures perfect contact, and, consequently, prevents the burning of the electrode holders and the cost of replacement of these is entirely avoided. When using these electrodes two sets are generally provided, which are worked alternately. When it is necessary to lengthen the electrode it is removed from the furnace and allowed to cool while another length of electrode is put into the furnace, the whole operation requiring only a few minutes. The short electrode has then a new length of tubing welded on to the short end and a special paste is carefully rammed into the tube and the electrode is again ready for work.

Cost Items.

Power.—This varies from 650 to 800 kilowatt-hours per ton, according to the nature of the scrap, the material to be made, and the efficiency of the shop.

Labour.—One melter, one helper and one or two labourers are employed on the furnace itself, depending on its capacity.

Electrodes.—The consumption of amorphous electrodes is usually from 30 to 40 lbs. per ton, and of graphite 12 to 16 lbs. per ton.

Repairs.—The life of the roof varies with the size of the furnace and other conditions, and between 80 and 200 heats can be obtained. The banks of the furnace are generally fettled between the heats, so that they last a considerable time.

Other Charges. — Additions, tools, overhead charges, ladle, etc., vary according to the class of steel being made and the shop conditions.

Operating Details.

In operating an electric furnace for making steel the cold scrap steel is thrown on to the hearth through the door after the furnace has been carefully dried out and heated up, or, in the case of a furnace that is in operation, after the furnace has been fettled from the previous charge. When charging is completed the current is switched on and kept as constant as possible, either by hand or an automatic regulator. The metal soon begins to melt, and during this period the flux is added.

This consists of a mixture of lime, fluor spar, and iron ore or scale. The slag formed floats on the top of the metal and the chemical reaction of refining takes place. The carbon in the steel scrap is oxidised by the oxygen from the iron oxide in the iron ore or scale, and is given off as carbon monoxide. This gas rising through the bath produces the appearance of boiling, and has the effect of thoroughly mixing the flux and the metal. The silicon, manganese, and phosphorus in the bath are oxidised by the oxygen from the iron oxide. The oxides of silicon and manganese are dissolved in the slag and the oxide of phosphorus combines with the lime to form phosphate of lime, which is also taken up by the slag. A portion of the sulphur oxidises and passes away as sulphur dioxide.

When sufficient time has been allowed for these actions to take place the current is switched off and the slag is run off by tilting the furnace. Sufficient carbon is then thrown in to provide the necessary percentage of carbon in the steel, and a second flux is added of lime and fluor spar. The phosphorus, silicon and manganese have been removed by the first slag, but the bulk of the sulphur and a certain amount of iron oxide still remain. This iron oxide is soluble in the second flux, and is removed by the addition of finely powdered carbon, such as anthracite dust, which reduces the iron oxide and, at the same time, forms a reducing atmosphere in the furnace. By reducing is meant taking up or absorbing oxygen from any oxide. The sulphur is also gradually taken up by the slag, and, at the end of the second purification, the metal is ready for tapping.

Melting Grey Iron.

The use of the electric furnace for producing grey cast iron has been adopted to a limited extent in America, and furnaces lined with either acid or basic materials have been adopted for this purpose. In the electric furnace, acid or basic, the regulation of the carbon is easy and accurate. The mixing of cast iron and steel in the electric furnace produces the truest semi-steel known, and it lacks the uncertainty of the semi-steel melted in a cupola. In the basic electric furnace there is generally a loss of silicon from 0.1 to 0.2 per cent., but in an acid-lined furnace there is no loss. With a basic-lined furnace the silicon can be increased by the necessary additions of ferro-silicon.

Grey iron can also be produced in the electric furnace by melting mild steel and raising the carbon content of same by the addition of a carburising agent such as coal or charcoal. The process used is similar to melting steel scrap for steel castings, the metal charged being first melted as in making a steel heat. The carburising agent is then added to the surface of the bath, and the latter thoroughly agitated until the required amount of carbon has been absorbed. The desired percentages of silicon, manganese, and phosphorus are obtained by the addition of these elements in the form of the ferro-alloys. The economic factors which govern the possibilities of making grey iron by this method are the relative costs of pig-iron delivered in a given district, and the net value of steel and iron scrap which can be obtained in that district.

Ajax Wyatt Furnaces.

The Ajax Wyatt furnace has been the most successful of induction furnaces, and has proved entirely satisfactory for brass melting where the output is sufficient to keep the furnace running continuously. This furnace is now the standard melting equipment for supplying brass rolling mills and extrusion plants. In consists of a cylindrical steel vessel lined with brickwork or rammed refractory material below which a transformer is suspended, the secondary of which is a vertical V-shaped channel arranged so that it passes round the primary winding and iron of the transformer. Heat is generated in this secondary, and the metal is then circulated by electrical forces, so that hot metal is constantly forced out of the secondary and cooler metal takes its place. This mixing effect is due to three forces, namely, convection currents, electric motor effect, and " pinch " effect.

In starting up these furnaces molten metal is poured in to fill up the V-shaped channel or secondary, and then cold metal is charged into the body of the furnace, and, as the metal in the V-shaped channel becomes superheated by the induced current, it circulates upwards out of the channel, and thus melts the metal above it. The usual size of furnace is 600 lbs. capacity, and one charge is melted per hour, with a current consumption of about 220 to 240 kw. per ton. When the furnace is not running, or when it is on stand-by during the week-end, there is always molten metal left in the channel, which is kept molten with a current consumption of about 8 units per hour.

After the furnace has been started and the first heat poured, sufficient molten metal is always left in the furnace to keep the channel filled, and then, after the furnace has been tilted back from the pouring position, the next charge of swarf, scrap or ingots is charged. When the whole of the metal is melted down and has reached its correct pouring temperature, the needles of the instruments will begin to oscillate, owing to the varying conductivity in the channel. This is very interesting and extremely useful, for it indicates the correct pouring temperature of the metal, and so does away with the necessity of having highly-skilled melters.

TABLE I.—*Ajax Wyatt Furnace—Melting* 61-39 *Brass-in Birmingham.*

Wt. of charge. Lbs.	Total time. Hrs.	Mins.	Units used.	Lbs. per unit.	Units per ton.
610	1	0	68	8.98	250
610	1	0	58	10.50	214
610	0	45	58	10.50	214
610	0	44	48	12.70	176
610	0	55	56	10.88	206
610	0	50	52	11.72	191
590	0	49	51	11.56	194
590	0	53	58	10.15	220
590	0	44	53	11.22	199
590	0	55	46	12.80	175
590	0	52	55	10.70	210
590	0	50	50	11.78	190
590	0	58	59	9.67	232
7,790	11	15	712	10.92	206

When pouring the metal from the furnace, the rate of flow of the metal is under complete control, as the tilting of the furnace is carried out by means of a small electric motor. The controller is usually placed in the centre of the turntable, which carries the moulds, and the melter is, therefore, in the best position for observing the casting of the metal into the moulds. The metal in the furnace can be held at any required temperature by means of voltage regulation. The switching operation is very simple, and a single change-over switch is only required, as it is found in practice that only the voltage necessary for giving the full load and that for stand-by, are used.

The electrical design of these furnaces has required a great deal of care, but, in operation, they work with very little trouble, provided the refractory material has been carefully rammed in and properly dried out. The cost of refractories may be below 6d. per ton melted, but this figure can be exceeded if by any chance there is a failure of power supply; a careless preparation of the bottom, or any bad operation of the furnace on the part of the workmen.

The life of the linings varies from two to three months to two or three years, and, as the cost of labour and materials for ramming the bottom is from £30 to £40, this is not a serious item on an output of 600 to 1,200 tons per lining. In fact, some of the furnaces running in this country at the present day have had an output of 3,000 tons per lining, and are still running on the same lining, and in Sweden outputs of 6,000 to 7,000 tons per lining have been obtained.

Although the efficiency resulting from the generation of the heat within the metal itself is remarkable, it has its limitations, as suitable refractory materials have not yet been found to produce lining for metals of high melting point such as nickel alloys, steel, etc. Continuous research is going on at the present time to improve linings, and so widen the field of application of this method of melting.

Another point which requires consideration is the necessity of leaving enough metal in the furnace between heats to fill the secondary channel. This may be objectionable if it is desired to change the composition of the alloys frequently, but brass of different compositions can be melted from day to day, as the change in the composition can be adjusted. A considerable economy in the cost of making brass in this furnace is due to the accuracy of composition which is obtained.

The following figures show typical performances of Ajax Wyatt furnaces in the Birmingham district working under favourable conditions and casting extrusion billets.

The average cost of melting one ton of extrusion brass containing 60 per cent. copper and 40 per cent. zinc in a 600-lb. Ajax Wyatt furnace is as follows:—

	£	s.	d.
Power.—224 kilowatt-hours at 0.75d...	0	14	0
Lining and Repairs...........................	0	1	6
Labour.—One man per shift at £5, making 12 tons per week per shift of 12 hours......	0	8	4
Total	£1	3	10

From this total should be deducted the amount saved by reduction in furnace metal losses when compared with other melting furnaces, say 10s.

The cost of melting in ordinary pit-fires at different works in Birmingham varies considerably, but the following figures are a fair average cost per ton in works making 60-40 brass for extrusion billets under economic conditions.

	£	s.	d.
Coke	0	8	0
Crucibles	0	4	6
Repairs	0	1	0
Labour	1	2	6
	£1	16	0

There is, in nearly all cases, a saving of at least 1 per cent. in the loss of zinc, though methods of calculating losses are so varied that this figure may be different from place to place. There is no doubt that in many works the saving is considerably higher than this figure. The saving of 1 per cent. of zinc with spelter at £35 a ton is equal to 7s. per ton of brass.

After due consideration is given to the savings which are derived from the space saved, which would be required for the storage of coke and the expense of handling ashes, the improvement of working conditions and ease of handling, it will be seen that a reduction of working costs of at least £1 per ton is obtained. The following is a list of the Ajax Wyatt furnaces installed in the various countries up to October, 1927:—

Country.	No. of furnaces.	Total K.V.A.
United States	375	22,760
Germany	106	7,200
Great Britain	32	2,400
France	15	1,125
Other countries.. ..	62	4,080
Total	590	37,565

The total output of these furnaces in all countries is approximately 870,000 tons per annum, and most of these furnaces are of 60 kilowatt capacity, melting about 600 lbs. per hour. The extraordinarily rapid growth of this type of melting is due to the fact that, while making a more uniform product, it is also much cheaper to operate than the crucible furnace. The actual cost of power is usually slightly higher than that of the coke used in the crucible furnaces, but the saving in labour, crucibles, and zinc losses far more than counterbalance this cost.

Ajax Northrup Furnace.

This furnace is a newer development of the induction method of heating and uses current of a much higher frequency than the Ajax Wyatt furnace. Ajax Wyatt furnaces are usually run on frequencies of 25 and 50 cycles, but with the Ajax Northrup furnace these frequencies vary from 500 to 20,000 cycles. Until recently difficulty in generating the necessary high frequency current had limited the size of this furnace to a few pounds capacity, and such small high frequency furnaces were of the spark gap type, working about 20,000 cycles. These furnaces have been installed for various purposes, such as research work in laboratories, platinum melting, silica ware manufacture, and the melting of alloys of high purity. Within the last two years, however, motor generators have been perfected

TABLE II.—*Ajax Northrup Furnace—High-Frequency.*

Material.	Wt. of charge. Lbs.	Total time.		Units used.	Lbs. per unit.	Units per ton.	Remarks.
		Hrs.	Mins.				
Nickel silver	636	1	49	163.8	3.98	563	Cold crucible
,, ,, ...	636	1	18	121.8	5.23	428	Hot ,,
Common brass	636	1	4	105.5	6.02	372	Cold ,,
,, ,, ...	636	0	43	71.3	8.90	252	Hot ,,
Copper	636	1	9	115.0	5.53	405	Hot ,,

which will run furnaces up to 6-cwt. capacity with frequencies from 500 cycles to slightly over 2,000 cycles.

In these furnaces the metal is heated by induction in a high frequency field wherein there is no need of iron or a secondary of the type used in normal high frequency induction furnaces. This has a great advantage metallurgically, as the furnace itself is of very simple construction, consisting only of a crucible round which a spiral inductor coil is wound with a narrow intermediate space filled with zirconite or some other heat insulator. The furnace casing is made of wood, and this body holds the coil which can be either air-cooled or water-cooled, and inside of which is a mica sleeve. The crucible is placed centrally inside the coil, and the zirconite, or other heat insulator, is rammed up round it. The distance between the coil, which is usually at a temperature of about 60 deg., and the molten metal which may be at 1,700 to 1,800 deg. C., is only 0.75 in. in the small type of furnace and in the large 6-cwt. size the distance is about 2½ in. The temperature gradient is accordingly very steep, and the outside of the crucible is only just visibly red when the metal is molten. Hence it is obvious that the wear of crucibles on the outside is very little. In addition to this the crucible is well supported all over its outer surface by the well-packed zirconite, which eliminates any tendency for the crucible to break owing to the weight of the charge.

TABLE III.—*Ajax Northrup Furnace—High-Frequency.*

Material.				Wt. of charge. Lbs.	Total time.		Lbs. per unit.	Units per ton.
Cu.	Ni.	Zn.	Pb.		Hrs.	Min.		
80	20	—	—	440	0	57	3.79	591
80	—	20	—	660	1	1	4.83	464
85	—	15	—	660	1	18	4.22	531
90	—	10	—	660	1	11	3.86	580
64.5	18	17.5	—	660	1	6	4.30	521
61.5	—	37	1.5	660	0	57	5.53	405
65	—	35	—	660	0	58	5.49	408
63.5	15	21.5	—	660	1	1	4.83	464
67	19.75	13.25	—	660	1	17	3.85	582
65	10	25	—	660	1	7	4.48	500

The life of crucibles in a large number of heats of cupro-nickel and nickel silver was 58, which was increased to 95 by proper fettling between heats, but it was found to be doubtful whether the delay caused by this patching or fettling was justified by reduced costs. The cost of high frequency furnace melting is about equal to that of a small Héroult arc furnace, as the power consumption, including all losses, is about the same, and the extra cost of crucibles is approximately equal to that of electrodes.

Steel made in this furnace is made under crucible conditions, but with the advantage that absolute homogeneity is obtained due to the intensity of the mixing. Heating and melting are effected very rapidly, as induction heating makes it possible to generate heat throughout the charge of metal simultaneously, instead of heating from the surface only, as is the case with all fuel furnaces. For melting operations and the heating of bars this is sometimes advantageous, as the risk of oxidation and contamination from furnace gases is reduced, and, for making small castings, the frequent melting of small quantities facilitates economy in general foundry practice. As an example of speed it is possible to melt 18 per cent. tungsten steel, 3-cwt. lots, in 45 minutes, which is less than one-quarter of the time normally required to melt one-third of this charge in a crucible in a coke fire.

As compared with pit fires this furnace has the advantage of avoiding all contamination with sulphurous fumes and other impurities. Labour costs are reduced and skilled casters of exceptional strength are unnecessary, while absolute control of heat and complete mixing are obtained. The space occupied by coke or ashes is no longer required, while chimney and furnace repairs are eliminated. Crucible costs are reduced to a fraction of those of pit fires, but, on the other hand, capital expenditure is considerable, and a skilled electrician is required for the rotary machinery.

The refining and purification of steel in high-frequency furnaces is a question that is receiving much attention. In many cases tool-steel makers have no desire to refine, but there are cases of interest, notably in connection with heat-resisting steels and alloys, in which absence of carbon is desired. It has sometimes been supposed that refining would not be possible in this type of furnace owing to the comparative failure of the old induction furnaces of normal or low frequency, which have a bath of complicated form with narrow channels, an excessive slag line on the refractories, and which work with low-temperature slags. The arc furnace is an efficient refiner owing to its high slag temperature, but it is only when successive particles of steel are brought into contact with hot slag that refining occurs, and the speed of refining necessarily depends upon the rate at which the impure steel is submitted to the refining action of the lower slag surface.

TABLE IV.—*Ajax Northrup Furnace—High-Frequency.*

Material.	Wt. of charge. Lbs.	Total time.		Units used.	Lbs. per unit.	Units per ton.
		Hrs.	Mins.			
Stainless steel ..	336	0	52	116	2.91	770
Carbon steel ..	400	0	54	140	2.86	783
High speed steel..	450	0	58	154	2.93	764
High speed steel..	450	0	50	149	3.02	742
High speed steel..	450	0	50	148	3.04	736
High speed steel..	450	0	48	150	3.00	743
High speed steel..	450	0	50	160	2.82	794
Nickel iron ..	336	1	30	167	2.05	1,092
Nickel iron ..	336	1	5	125	2.72	823
Nickel iron ..	336	1	10	131	2.60	861

In high-frequency furnaces the electric current causes a very rapid rotating movement of the metal in the vertical planes, the speed of rotation being so great that in a bath of steel 15 in. in diameter the centre of the bath rises more than 1 in. above the circumference. This rapid circulation of the metal in contact with the slag refines the metal, the heat transference between the metal and slag being sufficient to maintain the latter in a fluid condition and to ensure that intimate contact which is so essential to rapid and efficient refining. For example, a bath of steel containing 0.7 per cent. of carbon was left in contact with a slag containing iron oxide for 10 minutes, and the carbon was reduced to 0.24 per cent.

The remelting of low-carbon chromium steels without any increase of the carbon contents is an industrial application of the utmost importance for the recovery of scrap, stainless iron and heat-resisting alloys. The remelting of these alloys without absorption of carbon or impurities from furnace gases has now become a commercial possibility. The following analysis of a stainless-iron ingot made from carbon-free ferro-chrome and a Swedish iron of exceptional purity indicates that very low carbon alloys can be made without difficulty, *e.g.*, chromium 13.5 per cent., carbon 0.03 per cent.

Installations for the manufacture of tool steel usually consist of furnaces of 400 to 500 lbs. melting capacity and each supplied with 150 k.v.a. from a motor generator, the power factors of the furnace being corrected by condensers. The output of such a furnace is about 450 lbs. per hour, or about 4 tons per 24 hours, the exact output depending upon the quality of the steel made and the number of ingots cast. The furnaces are placed below the working platform so that the top of the furnace is on floor level, which is convenient for charging and for slag removal before casting. The ingots or moulds are arranged so that the steel is cast direct from the nose-tilted furnace, a tundish being used to avoid cutting the moulds. The moulds are placed so that their tops are at the same level, and, when a number of small ingots have to be poured, the moulds are brought before the spout of the furnace at the correct level and distance by a suitable turntable and ball bearings. A spare body consisting of a wooden box with spare coil, crucible and refractory sand is provided and can be put in position in a few minutes when it is necessary to change crucibles.

Another typical application is the use of these furnaces in foundries making small castings. For example, a foundry making motor-car castings, where the average weight is between 2 and 3 lbs., can reorganise the system of moulding and general layout so that the moulds can be brought up to the furnace or furnaces on a travelling conveyor, and so ladles and hand shanks can be eliminated. There is no loss of heat by transfer to a ladle or hand shank, and the furnace being well heat-insulated keeps the steel hot through the casting period. For small repetition work this method of melting and casting offers obvious advantages.

It is interesting to compare the effect of stand-by losses on an Ajax-Wyatt furnace with the conditions when operating an Ajax-Northrup furnace, which has no stand-by losses during idle hours, but has a lower overall efficiency for the conversion of energy from the electrical supply main to useful heat units. In the latter case high-frequency energy is generated by a motor generator which has an efficiency of only about 72 to 82 per cent., according to the size or periodicity of the machine, the additional loss in the furnace itself reducing the overall efficiency to about 60 per cent., against 83 per cent. for the Ajax-Wyatt furnace. If the two furnaces be worked 8 to 10 hours per day for 5½ days per week, it will be found that the Ajax-Northrup high-frequency furnace is about equal in efficiency and possesses sufficient marked advantages for numerous difficult metallurgical operations. The capital expenditure per kilowatt installed is approximately the same for the two furnaces, and the operating cost of the Ajax-Wyatt furnace is lower for continuous operation.

The scope of high-frequency melting is expanding as rapidly as electrical machinery constructors can meet the requirements imposed upon them, and progress both in the melting and heating of ferrous and non-ferrous materials is being rapidly accomplished. Its value is already well established as a method of making crucible steel, nickel-copper alloys, high-copper alloys, metals requiring great purity, and high melting-point metals of remarkable homogeneity and purity, with the elimination of the hard physical labour inseparable from present methods.

DISCUSSION.

The CHAIRMAN (Mr. J. S. G. Primrose) said the frequency of the electrical current used with the Ajax Northrup furnace was comparable with the frequencies associated with radio and wireless experiments. To induce in the metal inside the crucible the rapid electrical oscillations which generated the heat required to melt it quickly was a remarkable contrast to the ordinary methods with oil or coke, and the description of the process as "melting by wireless" seemed to have appealed to the popular fancy.

The Question of Relative Costs.

Mr. S. G. Smith said only that week he had read in a weekly periodical a reference to melting steel by radio and it had been very interesting to him to hear the explanation given by Mr. Primrose. Would Mr. Primrose put into terms of £.s.d. the comparison of the respective costs of melting (say, 500 to 600 lbs. of gun-metal) by the Ajax Northrup furnace and by other types in general use with coal, coke or oil. Such information would be a valuable addition to the paper. Mr. Primrose had, indeed, given certain figures of the average cost of melting one ton of extrusion brass (60 copper, 40 zinc) in a 600-lb. Ajax Wyatt furnace. He understood that the £1 3s. 10d. per ton given included overhead charges and everything else, which was a very low figure. The corresponding figures for melting with ordinary pit fires were stated by Mr. Primrose to be £1 16s. In that comparison the Ajax Wyatt came out very favourably, and taking into consideration other advantages it possessed, such as cleanliness, he was brought to the conclusion that the sooner the electric furnace was installed in the brass shops and iron foundries of this country the better it would be for the industry. Could Mr. Primrose hold out hopes that the electric furnace would displace the cupola? He understood that at present the obstacle was the matter of installation and running cost. But it had been in his mind for many years that the electric furnace could be turned to useful account in many large works where turnings and borings accumulated, as it could convert them into commercial metal.

Mr. Primrose said he had no figures with regard to the melting of gun-metal in the Northrup furnace; the furnaces of which he had been speaking were installed for high-speed steel melting and his audience might be interested to hear how the costs compared in that case. In Sheffield, with the ordinary coke fire method, the cost of producing a ton of high-speed steel varied from £13 to £18 per ton. With the Ajax Northrup method, taking power at 0.75d. per unit, the power cost £2 13s. per ton, crucibles cost 17s. 6d., and the items for labour, overhead charges and royalty brought the total to £9 per ton. Thus there was a saving of £4 to £9 in the melting of high-speed steel. That was based on a furnace of 450-lb. capacity. The figures he had already given for the Ajax Wyatt, £1 3s. 10d. against £1 16s. with the ordinary coke-fire method, operating in the Birmingham district, also showed a considerable saving.

He did not think there was any prospect of these furnaces replacing the cupola. Cast iron was a comparatively cheap product and the cupola was a cheap method of producing it. High-speed steel, platinum, nickel-silver and other alloys were expensive materials, and the people who were handling them could afford to pay a fair amount for plant. In an iron foundry if the manager said he wanted £4,000 or £5,000 he did not get much encouragement; some people would want a new foundry for that amount.

Hitherto the Ajax Northrup furnace had been much limited in capacity. Those he had described were not more than 450-lb. capacity, but now in America one of 1-ton capacity was being built, so that a big advance had been made. When it was introduced in this country the trouble was to get the electrical generators required; in fact they could not be had from British firms and had to be brought from abroad. In the last year or two, that had been changed, and British manufacturers were making generators which gave the frequencies required, from 500 to 2,000 cycles, and the furnaces which were now being installed were equipped with generators which were entirely British.

Electric Ore Smelting Furnaces.

Mr. E. Longden said he believed in America electric furnaces were being used for the reduction of ore into iron. They were constructed something after the fashion of a blast furnace with the electrical arrangements adapted in a suitable form. The ore was in the form of oxide and it was brought into contact with carbon at certain temperatures. It was established that it took a ton of fuel to reduce ore to a ton of iron in the blast furnace; in the electrical furnace something like a quarter of a ton of fuel was consumed in producing the same quantity of product. As an off-set against that there was the great cost of electrical energy. The use of electricity for melting steel had great advantages. A higher temperature could be obtained, the metal was more fluid, a thinner section of casting was possible, whilst the metal would run more freely. It gave greater solidity to the mould metal, but the information given to him by people who had a great deal to do with steel castings was that the improvement in them was not absolutely due to electric melting, but arose partly from superior moulding practice. The mould had to be made to take the metal at the higher temperature, and greater care had to be given to the preparation of the mould, which resulted in better castings.

Electric Steel Demands Superior Moulding Practice.

Mr. Primrose said many people who had installed the electric furnace had given testimony to that effect, saying the metal was of better quality and freer from blowholes. It was true also, as Mr. Longden suggested, that the preparation of the mould helped a great deal.

Mr. Longden: Does Mr. Primrose think there is actually any great advantage in melting cast iron by electrical energy?

Mr. Primrose replied that it depended on the conditions existing in the particular district which was in question. In the United States, electric furnaces were being used for this purpose where pig-iron would have to be brought from a distance. The economic factor was the deciding consideration, and was based on the price at which pig-iron could be delivered and the price at which steel and iron scrap could be bought. .

Increase of Capacity to Widen Scope.

Mr. R. A. Miles asked whether the lecturer had any records of the use of the Ajax Northrup for melting brass swarf.

Mr. Primrose replied in the negative. He added that it ought to be realised that the last furnace he had been describing was only a "baby," which would certainly grow up and have much wider application. It could be applied to the melting of any metal. Just now the capacity was small, but it could be raised to 1 ton or even 3 tons.

Mechanically Charging Electric Furnaces.

Mr. Longden asked whether there were any means of mechanically charging large electrical furnaces. He recollected that in a foundry at Philadelphia he saw the charging done by a gang of niggers.

Mr. Primrose said with the open-hearth furnace one could take the charge in loading boxes and place it in the furnace by means of a charging machine, but that was in a furnace with ample internal space, and it was not possible to charge like that in the electric furnace. In the electric furnace the charge was small compared with an open-hearth furnace charge, so that it could be charged by hand.

Applicability to Aluminium Swarf.

Mr. Miles: Would you recommend it for melting pure aluminium or aluminium swarf?

Mr. Primrose said aluminium alloys, though not pure aluminium, had been melted in a demonstration furnace which had a frequency of 1800 cycles. That was rather high as 500 cycles would be sufficient. In Birmingham high-copper alloys and nickel-copper alloys were being melted in a furnace of 500 cycles, and that frequency would be suitable for aluminium and aluminium alloys. The furnace was quite suitable for aluminium swarf.

Mr. Brereton asked whether it was advantageous to stir the aluminium and whether pure copper could be melted in the Ajax-Wyatt furnace—alloying elements being added later?

Mr. Primrose said in melting aluminium with the Ajax-Northrup furnace although the aluminium was circulated by convection currents no air reached it, and there was no oxidation of the ingots. With the Ajax-Wyatt furnace, 200 lbs. of broken brass was put in the slot, and after that they could charge in the brass scrap or brass swarf or copper on the top, and make final additions of zinc. But the Ajax-Wyatt furnace would not melt copper, and in any alloy the maximum amount of copper it would melt was 85 per cent.

They had not been able to get a refractory which would stand up to a higher copper percentage than this figure. That was where the Ajax-Northrup came in. It would melt copper alloys up to 90 per cent. or higher, and was quite satisfactory.

Effect of High Installation Costs.

Mr. Makemson said the figures of operating costs given by Mr. Primrose showed a considerable advantage for the electric furnace, but how far was that counterbalanced by increased interest on capital outlay and depreciation? Certainly the initial expenditure was much greater than with the ordinary method.

Mr. Primrose said in the case of furnaces now operating in Birmingham it was reckoned that although the initial cost was considerable it would be cleared off with one year's working due to the savings effected.

Mr. Hopwood observed that from practical experience in melting nickel silver in the ordinary crucible in the ordinary pitfire they could get 12 to 18 heats with one crucible. That was using half-pots. If it was an 80-lb. pot they would be melting 40 lbs. in it.

Comparative Costs Other than Pit-fired Crucibles.

Mr. George Hall said in considering the adoption of the electric furnace for general foundry practice the determining factor would be the cost, and he would be glad if the lecturer would give comparative figures in respect of the Ajax-Wyatt and also in respect of the Morgan type coke-fired furnace of 400 to 600 lbs. capacity. Would Mr. Primrose recommend that the Ajax-Wyatt should replace the old-fashioned air furnace for melting down 80 per cent. copper and 20 per cent. tin. He remembered melting 5 tons of that metal with a coal consumption of 15 cwts. of coal at 15s. per ton. It was an old-fashioned furnace with just a small blast attachment.

Mr. Primrose said comparing an Ajax-Wyatt of 600 lbs. capacity with a coke-fire furnace of similar capacity, the initial cost was greater in the former. But 3,000 tons of brass, and more, could be melted with the same lining, so that although £30 to £40 might be spent, the real cost was less than in the latter case with a crucible costing £3. There was really a big saving in crucibles.

With regard to the melting of gun-metal or high-copper alloys, the Ajax-Wyatt furnace was not suitable for such alloys as no refractory had been obtained to stand up to them. Although the initial cost of the Ajax-Wyatt was high there was the advantage that the metal was produced free from contamination by gas, which was often a big trouble in the brass foundry as it led to a high percentage of scrap. In the Ajax-Northrup furnace the melting zone was as nearly as possible a pure melting operation, and in the years to come furnaces of this type would be employed largely for all metal melting. At present it was too small, and could only be applied to high speed or crucible steel, pure metals or expensive alloys.

Mr. Primrose added that he had melted as much as 7½ tons of gun-metal in air furnaces using coal in about the same proportion as Mr. Hall had mentioned, but occasionally they had considerable trouble with porous castings; they did not always know the cause, but it was probably due to gases picked up during melting.

West Riding of Yorkshire Branch.

HIGH-SILICON ACID-RESISTING IRON.

By Ellis Whitaker.

Since the chemical industry began to be seriously established in this country, the subject of high-silicon iron for acid resisting has been an important one, and perhaps to-day we may be advancing, if we have not already advanced, into the iron age, as applied to plant for this industry. For many years past considerable study has been given to the question of acid-resisting cast iron, and it has been one of the most fascinating studies of the metallurgist for the last few years.

To some extent the European War has been responsible for such progress, and a great amount of research work was carried out. Future generations will doubtless be able fully to estimate what an immense amount of improvement has been accomplished during that period alone.

Since necessity is the mother of invention, the dire necessity arose during the war throughout Europe of obtaining better and more efficient plant to deal with acids. In those days money was more freely expended on metallurgical research, and we owe much to the chemist for his assistance in helping us to find a suitable metal, in the form of iron, which would withstand the corrosive action of sulphuric acid or nitric acid. It has been proved long since in the laboratory that a pure form of iron could be rendered resistant to either sulphuric or nitric acid, by addition of a suitable proportion of silicon.

It is particularly noteworthy that silicon present in a lesser quantity than 12 per cent. has little or no greater resistance to corrosion of acids than a good ordinary cast iron, whilst on the other hand it has been proved with equal certainty that any excess of silicon over 16 per cent. gives no added resistance to corrosion, consequently in producing these high-silicon irons for resisting acids, one is compelled to work between fairly narrow limits, to preserve the acid-resisting qualities desired, and the graphite carbon content must be at a low figure, about 0.6 per cent. being the limit. If any excess serious difficulties arise in thick sections forming pockets of graphite where two sections of metal join together, and samples are seen from time to time of broken castings, by reason of an excess of graphite in the metal.

Composition Specified.

The phosphorus content must also be restricted to about 0.2 per cent., sulphur about 0.05 per cent., manganese about 0.3 per cent., whilst the best work has been done with silicon at 13 to 15 per cent. A normal average pig-iron may show Si 3.45, S 0.03, P 0.64, Mn 0.66, C.C. 0.27, Gr 3.48 and Fe 91.47 per cent.

To produce an acid-resisting iron it is necessary to get rid of the impurities, and form as pure a form of high grade iron as possible.

The general structure of this high-silicon acid-resisting iron is evidently a solid solution of silicon in the iron, with fairly small graphite nodules uniformly distributed throughout. The contraction of this material is about 3/16ths of an inch per foot, whilst ordinary cast iron is 1/10th of an inch per foot.

The manufacture of these castings requires craftsmanship of the highest order, and in spite of the success already obtained, there are many difficult factors to be overcome, and all alloys of low-silicon content, under 12 per cent. are attacked very readily by these acids. For condensation of nitric acid high-silicon metal was found a great boon, as plants of large capacity could be constructed very rapidly, which could not have been if pottery were used, owing to the length of time required for its manufacture. The production of these castings in acid-resisting iron is a trade somewhat jealously guarded, with the firms who make this class of work, but the author obtained a great amount of practical experience, which was most interesting and at the same time important. This material is largely employed so as to avoid using earthenware sections. The qualities of an acid-resisting material are many and various, and must have sufficient tensile strength to withstand rough usage, and must be proof against cracking owing to sudden changes of temperatures. It must also be machineable and withstand the strain when bolts are tightened at the joints, and of such a nature that the foundry can make castings of desired shapes and sizes, whilst retaining acid-resisting properties which compare favourably with porcelain, which has the highest resistance to corrosive acids.

Factors Influencing Success.

Great care must be given to the melting process, and temperatures of melting and casting should be as even as possible, in some cases casting designs have to be altered, to overcome the difficulties of moulding. This material is replacing earthenware, owing to the latter cracking with alternate heating and cooling, thus hindering the output.

This metal is a complete success, and the condensed acids are equal in purity to that produced by any other system of condensation. The life of this alloy is practically indefinite as some plants have been in use several years, and are yet doing good work. They have been the means of keeping down maintenance costs, and thus causing a great saving by its long life, compared with other materials previously employed, as plants which were closed down for periods for complete overhaul are now very rarely closed down for repairs since this material was put into use.

It is not thought desirable, however, that reference should be made to its trade name, as it has a world-wide reputation. It melts at 1,200 deg. to 1,300 deg. C., and the loss of silicon is about 0.5 per cent. in the cupola. Great care should be taken to see that the bed is well burnt up before charging, as this facilitates the production of good hot metal at the first tap, and avoids pouring into ingots. As the metal leaves the spout and drops into the waiting ladle or shank, a fluffy layer of shining graphite covers the surface, which is skimmed off. By the time the metal reaches the mould, it is again thickly covered, and this must be skimmed off quickly and the job cast. The material requires to be handled quickly, as graphite precipitates very quickly and soon solidification takes place. For every 1 per cent. of silicon introduced about 0.3 per cent. carbon is thrown out of solution, at or before the moment of solidification, manganese and sulphur in small quantities are regarded as unimportant. The floating kish is sometimes trapped in some types of castings, and this causes them to leak under pressure. Some of these castings have to be liberated quickly, owing to contraction, as the material is of a fragile nature, and these have to be bared so that cooling should be as even as possible throughout the casting. This is not a happy job for the man in charge, for the following morning he sometimes finds disaster, and learns much by experience.. The running of the castings play a great part, the easier the flow of metal the less graphite separation, as when the metal dashes against the core the graphite is violently disturbed and readily freed, and floats around the surface of the casting. This kish cannot be eliminated by skimming, and is always a danger to a weak casting, and many sound castings contain kish somewhere about them which cannot be found except by testing, where the pressure limit is 50 lbs.

Studs should be avoided on cores as much as possible, but if they are used they must be of the same material, or the acid will quickly eat them away. Acid-resisting cast iron has many times the life of stoneware, and a charge of nitric acid takes about 17 hrs. This was usually found to take about 36 hrs. when using a similar condenser built in pottery, thus a greater production can be made from plants installed in acid-resisting cast iron, and the chemical industry have found great advantages, so praise is due to the research workers in guiding the foundry to success in manufacturing this material.

Discussion.

A MEMBER said he understood that acid-resisting iron castings would have to be ground, and not machined.

MR. WHITAKER agreed, and pointed out that they could be machined at a slow rate, and a facing made on them, but they could not be threaded.

Mr. W. H. Poole (Keighley) asked what was the size of the gate as compared with the gate used for an ordinary iron?

Mr. Whitaker said they should be gated with a good down-gate and have a short connection with the runner well up to the casting, so that it could get the feed well through. It required more runners. He gratefully acknowledged that he had received considerable help from Mr. Poole and Mr. Forrest on the technical side of his Paper, and also the loan of some useful lantern slides by Mr. Poole.

Practical Details Desired.

Mr. Poole asked could Mr. Whitaker say whether there was any great difference in practice required in melting these irons as compared with ordinary metal as to blast conditions, the amount of coke required; what particular types of pig-iron were usable; and a little more information as to the actual melting of running metals? Mr. Poole said it seemed to him that in the gating and feeding of these castings there lay the chief factor for success. Another interesting point would be the questions of the best sands to use. He assumed this metal was very hot and rapidly solidified, and handling of it must be quite a fine art. The question of the coating of the mould and the sands would be very interesting. The errosive effect on the mould, he thought, must be something which they did not encounter so much in ordinary work.

Mr. Whitaker said that in some cases it was necessary to skin dry the moulds. Some steel was used in the furnace charge, and sometimes cast-iron scrap containing about 10 or 12 per cent. silicon as a basis. Additionally ferro silicon was added to the cupola charge. This high silicon content was supposed to throw the graphite out of solution to a certain extent.

Kish in the Receiver.

Mr. H. Summersgill said he would like to know whether, in the use of these metals, the graphite had a dirtying effect on the receiver, thereby possibly causing trouble.

Mr. Whitaker said it left a kish behind it, but if there was any trouble it was more in the metal in the ladle, but he agreed that it did soil the receiver a good deal.

Mr. Poole remarked that they were sometimes liable to get this kish effect with an ordinary grey iron when they achieved a very hot melting condition. The higher the silicon content the less was the metal able to hold or retain carbon. The kish thrown out was quite light, and was trapped and sometimes could be seen floating about in the air. He had seen the same phenomenon on blast furnaces. The total amount of the residual graphite would be only about 0.6 or 0.8 per cent.

Bottom Pouring.

Mr. Summersgill asked had Mr. Whitaker any experience in the different methods of pouring this metal, and, if so, had he found any particular advantage in bottom pouring as against lip pouring?

Mr. Whitaker said all the castings were lip poured, and he knew of no advantage to be derived by bottom pouring.

Mr. Poole said bottom pouring from the ladle was done in some foundries, but as regarded the actual casting he thought top running for the mould was better, but from the ladle, bottom pouring might be an advantage.

Mr. Forrest said he thought the violent agitation of the metal would go against bottom pouring.

Mr. Poole replied that for light work he considered lip pouring essential.

Mr. S. W. Wise said Mr. Whitaker must have experienced many difficulties in the use of these irons which one did not have in ordinary cast irons. It would be interesting to know whether Mr. Whitaker had any difficulty with regard to contraction in putting the runner so near to the bar, because it must, Mr. Wise felt sure, be metal of high contraction.

Mr. Whitaker said if they thought the runner was anywhere near the bar they would liberate it as soon as possible or there would be a crack. Moreover, it would be necessary to ease the cores

Mr. Wise said he assumed this iron was necessarily a low carbon iron, and that the silicon would have a weakening effect on the casting, and there must be a good deal of difficulty in getting the men accustomed to handling it.

Mr. Poole said he was rather surprised to hear Mr. Whitaker say castings from these irons could be machined. In his own experience he had found them very difficult to machine; almost impossible to machine by the ordinary methods.

Mr. Whitaker said much of the work outlined had been machined, but there was no grinding. The lathe, he agreed, had to be run very slowly.

Widening the Foundry Industry.

Mr. A. Jackson, moving a vote of thanks to Mr. Whitaker for his lecture, said that the members had been very fortunate in having such a paper. It was certainly a specialised subject, but it was a subject of importance to all foundrymen, particularly under present conditions in the industry. His own feeling was that in the foundry trade to-day there was not really enough work to go round, and if attention could be drawn to new uses for iron castings it would be doing a real service to the industry—a much better service than the cut-throat competition experienced in the trade to-day. The particular use of this type of acid-resisting casting was, of course, in the chemical industries. The chemical industry generally was enjoying considerable prosperity, and he was convinced there was likely to be an increasing demand in that industry for castings of an acid-resisting character. The acceleration of that demand depended largely on the ability and willingness of foundrymen to produce this special work. The alternative materials to this acid-resisting iron, so far as concerned the chemical industry, were earthenware and porcelain, but neither of those materials could give such good service as cast iron of an acid-resisting quality, which also reduced the time involved in chemical processes and was therefore likely to be more and more in demand. Mr. Jackson said he believed it was in this direction that the salvation of the foundry trade was to be found. He believed it had been found that low temperature carbonisation also could be greatly speeded up by the use of cast-iron retorts instead of the fire-brick or silica brick hitherto in use. To his mind, the metallurgical troubles met with in these acid-resisting irons were slight compared with the ordinary practical troubles of the foundryman. Mention had been made of high shrinkage and brittleness, and the throwing out of this kish which tended to hinder pouring, and it was a great credit to men like Mr. Whitaker, who had grappled with these problems and had to a very great extent overcome them.

Experience Confirmed.

Mr. W. G. Thornton seconding the vote of thanks, said he had had some little experience with these irons and he could confirm Mr. Whitaker's statement that it was a most interesting job. Three or four years ago the firm with which he was associated had an inquiry for some tanks of acid-resisting material. They overcame all the troubles in regard to analysis, cupola practice, etc., but where they came up against the great difficulty was in the ordinary practice with these irons in the foundry. From the analysis point of view the dealing with these irons was simple if a firm had a chemist and the necessary tackle. The cupola part was simple to-day, but the difficulty was in the practice; in his experience they found they did not heat the iron quickly enough. One learned, of course, by mistakes, and he believed they were just getting nicely used to the job when they had to stop. Mr. Whitaker mentioned an interesting point in speaking of melting. The bed must be kept well up the cupola. In his (Mr. Thornton's) experiments there was trouble with gates and runners, but when they could gate them in the middle of a job they were satisfactory, but if placed at one end it filled up the flange. The more runners they placed on it the better. Mr. Thornton said he, like Mr. Poole, was surprised to hear Mr. Whitaker say castings from these irons could be machined. His experience was that the material would scrape, but he did not call that machining. In drilling a hole one could do about four revolutions per minute, and he did not call that machining. Boring a hole was very slow, and they could be ground more quickly than machined. In regard to sands, his experience was that a very open sand was desirable. Personally, he would advise top running invariably; if they bottom-ran, the carbon in solution would deposit kish right at the top of the casting. It was policy to avoid cores as much as possible, but when essential he used ordinary green sand. A very important point, he proceeded, was that of percentage of phosphorus. In his experiments they had 0.12 or 0.15 per cent., and if varied in the least it altered the carbon content. They found the phosphorus very difficult to control. They had to use a great deal of steel scrap to get the phosphorus down to what they required. The pig-iron used contained about 12 per cent. silicon.

Machining Troubles.

Mr. Welford said he would be glad to know what amount of super-heat was involved in Mr. Whitaker's castings. Most of the high-silicon irons, he believed, were proprietary brands, and the bulk of the responsibility when used was on the moulder. The tensile strength, Mr. Welford believed, was about 6 tons per sq. in., and the flange ought to meet that. He would like to know whether the machining, as spoken of by Mr. Whitaker, gave a clean surface. Personally, he thought it must be rather rough.

Mr. Whitaker: Yes, very crumbly.

Mr. Welford said that in cupola practice he thought light charges were the rule.

Mr. Whitaker replied that 4 to 4½ cwt. was normal, but the first two charges were about 3 to 3½ cwt.

Mr. Welford said he believed the iron was a mixture of wrought iron, steel, high-silicon pig and ferro silicon, and he believed antimony was also used, to the extent of about 0.1 per cent., and had a good influence. In making pipes, when the metal was run towards the end, he would presume that there was an accumulation of kish in the flange at the end.

Mr. Poole, supporting the vote of thanks, said Mr. Whitaker was to be complimented on having the pluck to bring before the Branch something that was quite new. Mr. Whitaker's experience was valuable to himself and also to the metallurgist, because he was able to speak as the craftsman on the job. Mr. Whitaker's Paper should be an encouragement to many other members to come forward to give their fellow craftsmen some little enlightenment by comparison of experiences and practical insight. Many members, he thought, could really provide very interesting and generally helpful Papers on their own particular line of work in the trade. A great deal of good must come of an ever-closer contact between the craftsman on the job and the technical man.

The motion was carried unanimously, Mr Whitaker briefly responding.

Scottish Branch.

MOULDING AND CASTING OF SMALL PULLEYS AND GEAR BLANKS.

By J. Longden (Member).

Many methods are in use for the production of such castings. The ordinary method of moulding by loose pattern is a slow and expensive method, which can only be justified where castings are few or occasional. A wide range of machines is now available providing for ramming by hand or power. In every case the type of machine adopted must be determined by local circumstances and requirements. It is

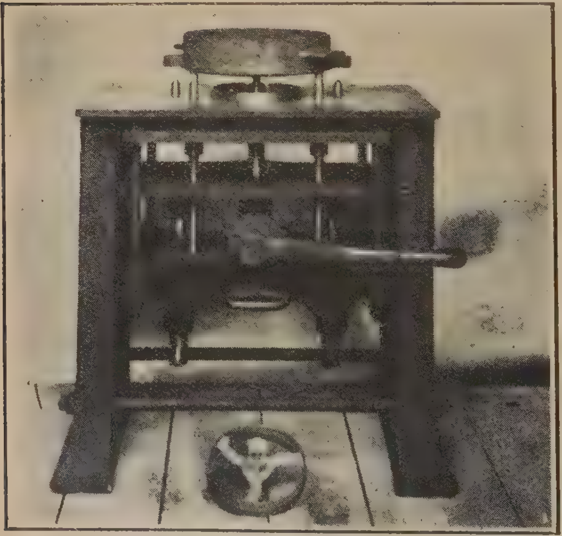


Fig. 1.

not intended to enter into a general description of these various types of machines, but to make brief reference to one or two hand-ramming machines. Fig. 1 shows a typical machine suitable for the making of pulleys (as well as other things). This is a German machine, made by the Badische Maschinenfabrik, of Durlach, as are also the next two to which

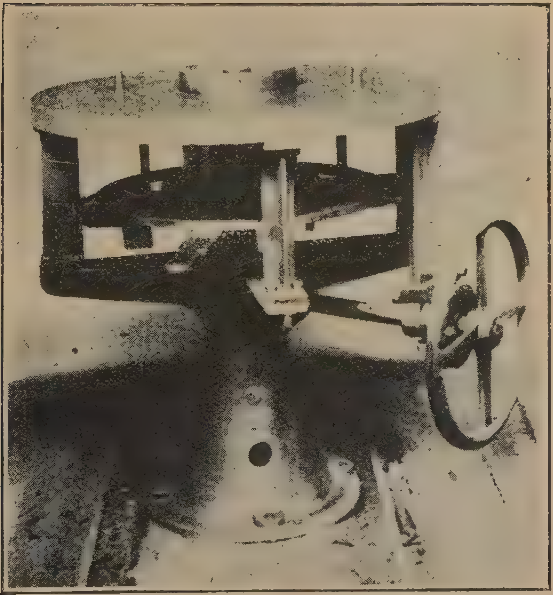


FIG: 2.

reference will be made. The photograph shows a mould rammed up and lifted clear of the stripping plate after the rim pattern has been withdrawn. The rim pattern is shown back in its position for ramming again.

Another type of machine is shown in Fig. 2. Deep lifts are possible with this machine, as pattern drawing is done by means of toothed bar, pinion and hand wheel.

For different sizes of pulleys, different patterns and stripping plates are attached to the machine. Owing to the deeper length of rim pattern which may be used on this machine, pulleys with double arms may be made without the aid of cores. The machine shown in Fig. 3 is of more interest and ingenuity. It is intended solely for the making of pulleys of various sizes on the one machine without the necessity for setting up fresh patterns. The machine is of similar design to the preceding one. The outer stripping plate carrying the box pins is permanent, but inside this, within limits corresponding to the size of the machine, a number of rim patterns (up to 21) are arranged telescopically, one within the other. These, when at rest at the bottom of the draw, sit flush at their top edges with the outer stripping plate. Any diameter rim which it is desired to use may be raised and operated as a single pattern on setting a pointer on a scale, the remaining patterns serving to strip the rim inside and outside. Loose half-arm patterns and bosses are used and suitably located with a view to exact registry of the top and bottom half moulds, both being made on the same machine. There are several good British machines of the hand-

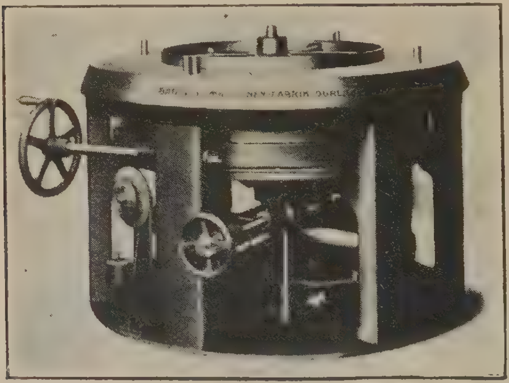


Fig. 3.

ramming type. Many people, of course, made their own. For many years the author has followed the practice which will now be described.

Author's Normal Practice.

The machine in use is the Adaptable (a Pridmore would be just as suitable), upon which pulleys are made up to a maximum diameter of 16 in. The pattern, as shown in Fig. 4, ready for the moulding box, represents a complete half of the casting. After ramming, the rim is drawn through the stripping plates; the mould is then lifted away. The boss pattern (which is loose, having a male and female locating centre) is lifted away with the mould, withdrawn, and replaced ready for the next mould. The pattern with rim withdrawn is shown in Fig. 5, the boss pattern having been replaced. As the arms of the pulley are bent it is obvious that provision must be made for the centre to give upper and lower impressions, in top and bottom moulds respectively. To explain this it is necessary to describe the details of the pattern. The rim pattern is attached to the movable carriages of

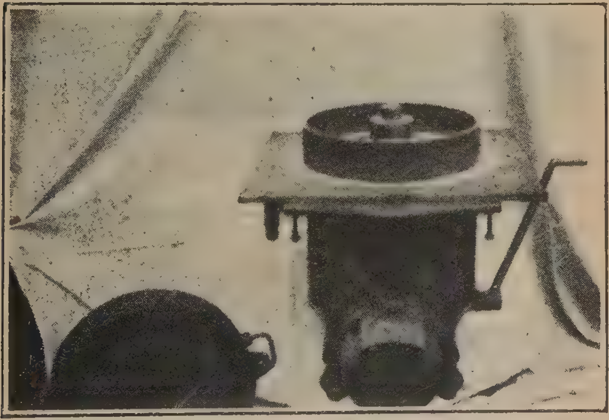


Fig. 4.

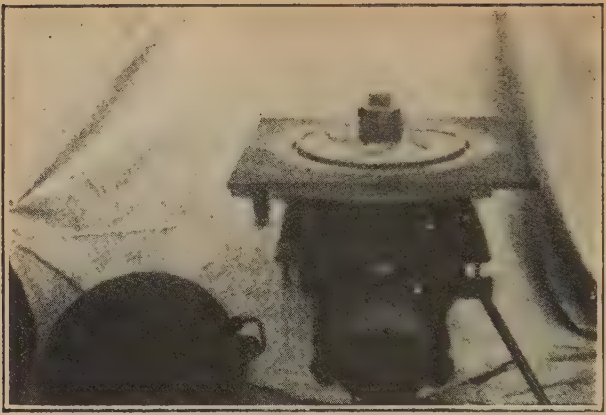


Fig. 5.

the machine, which lowers the rim to its limit on the handle being turned through 180 deg. The outer stripping plate is screwed down to the adjustable shoulders of the machine. So much is commonplace. A sketch of the casting is shown

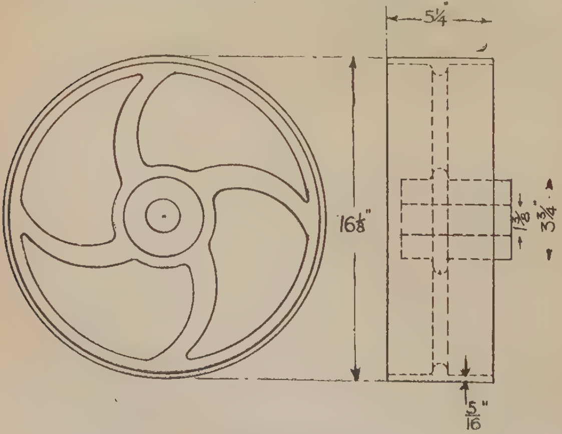


Fig. 6.

in Fig. 6. It is obvious that one half-pattern only would give top and bottom arm impressions which would not match. This is dealt with as

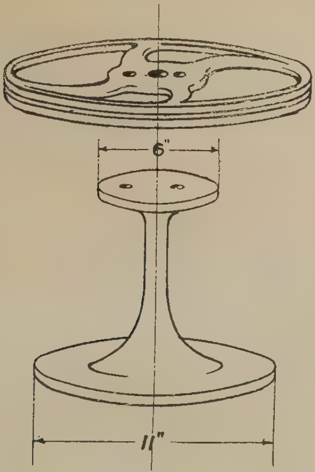


Fig. 7.

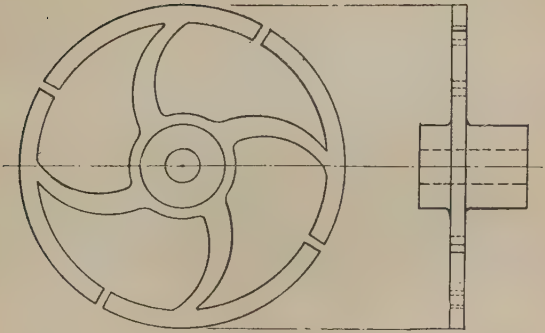


Fig. 8.

follows. The arm pattern is made in exact halves, without boss, in cast iron. Each half is machined on its flat joint face, screwed to the other, and highly finished. The halves are then taken apart and attached one on each side of a $\frac{1}{4}$-in. steel plate, which has been turned up on each surface and the outer edge turned to the inside diameter of the rim pattern. To secure that the half-arm pattern shall register properly, one half-pattern is laid on the plate, which is then drilled to the existing holes in the arm pattern. Both are then screwed to the plate, one on each side. At the centre of each half arm pattern a socket has been drilled, into which a spigot on the loose boss pattern fits. The two-sided arm pattern plate is shown at the top of Fig. 7, serving as centre stripping plate and arm pattern for both half

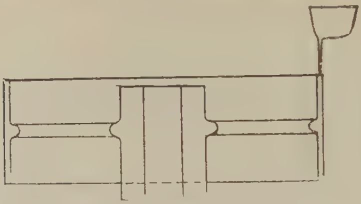


FIG. 9.

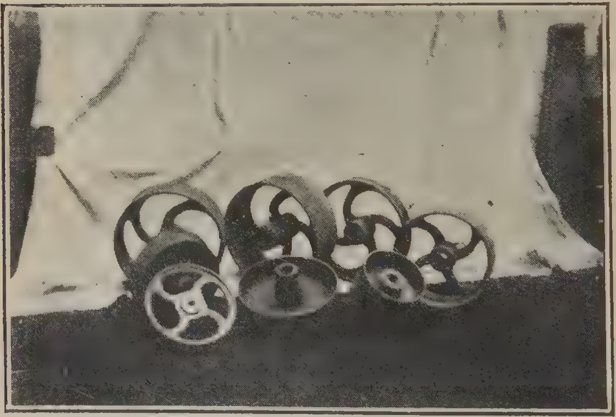


FIG. 10.

moulds, one side being used whilst bottom half moulds are being made, and the centre plate is then reversed whilst the top halves are being rammed.

It is of first importance that when the half moulds rammed on different sides of the centre plate come together they should register exactly. If on reversing the plate the slightest twist takes place, the castings are unsatisfactory. This is easily safeguarded. The chief registration is determined on the outer stripping plate. In drilling this plate for the box pin-holes a line is scribed through the mathematical centre of the pulley through the long axis of the stripping plate. This line must cut the pin-holes exactly into halves. This secures exact registry for top- and bottom-parts of the rim mould.

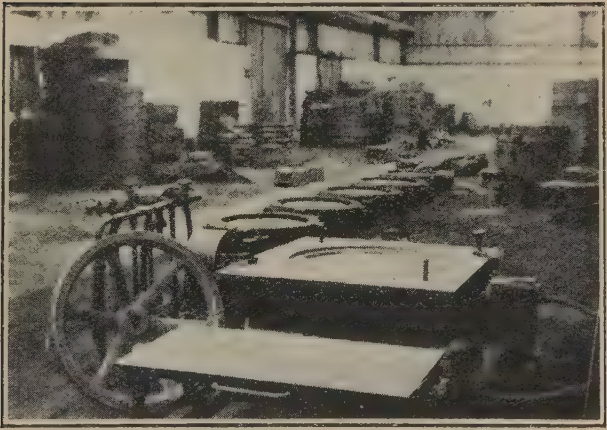


Fig. 11.

Using the Stripping Plate.

The middle stripping-plate, carrying the arms, has also a line on each half, which exactly divides the arm patterns across the diameter. At one edge of the inner plate and at the corresponding edge of the outer plate a slight incision is made, on the centre lines, just where they meet the rim, which serves as a permanent guide in setting the inner stripping plate. If, when this is reversed, the incision is exactly in line with that on the outer stripping plate, a perfect arm joint is the result.

The kind of stool used for carrying the inner stripping plate is of importance. The most convenient stool for the purpose is shown in Fig. 7. It is simply a bobbin of cast iron, machined on its upper and lower faces. The inner stripping plate rests on this. Two countersunk holes are bored through the arm pattern and centre plate, on the middle line, and the stool has corresponding tapped holes; which, however, are placed at different distances from, though on the same line, so that, on reversing, the plate must go into its proper place when screwed up.

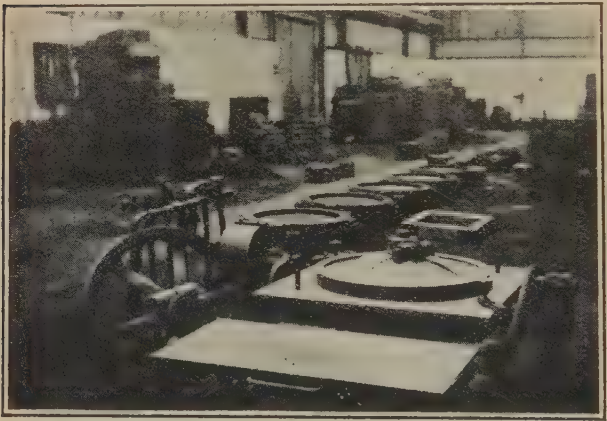


FIG. 12.

Though this description is lengthy, the work of setting the centre plate takes up only a minute or so. As the stool is rather heavy, it is only necessary to put the screws through the centre plate, tighten them up, and twist the stool round until the notches on the inner and outer stripping plates are in alignment. Work can then go on indefinitely. The stool does not need screwing down to the machine, owing to its weight. Care is needed that on the final adjustment the inner and outer stripping plates are on the same horizontal plane.

How Larger Pulleys are Made.

With the pattern described, a pulley of a maximum rim width of 12 ins. can be made, but the same pattern is used for every width of rim less than that. The usual method of doing this is to raise the outer and inner stripping plates to leave the necessary depth of rim. Where changes in depth are frequent, this method is cumbersome, and the author has adopted a simple plan. It is obvious that, in the act of withdrawing the rim pattern, by means of the handle, the rim is gradually reduced in depth to zero—over the stripping plates. Hence it is only necessary to provide a rest for the plate to which the rim is fastened at any given height. Into the under-side of the outer stripping plate, on opposite sides, two studs are screwed, on each of which revolves a little cam, which can be raised or lowered by suitable nuts on the stud. On the toes of the cams the pattern plate rests, at the height required. On the completion of ramming, the toes of the two cams are turned outwards by a simple movement, and the pattern withdrawn. Many widths and depths of pulleys may be made in this way; the webbed pulleys having a suitable plate centre in the pattern, instead of arms.

In the ramming of pulleys of this character it is found that care is needed to get sufficient solidity just at the joint, unsightly swellings otherwise resulting.

Governing Factors.

The strength and soundness of a pulley are conditional on (1) the metal of which it is made (2) the method of pouring; and (3) conditions of cooling. The author has found an iron of the following order to give easy machining on the rim, whilst allowing of soundness at the boss:—GC 3.2, CC 0.3, Si 2.25, Mn 0.5, S 0.08, and P 0.6.

Before discussing pouring, regard must be had to the following:—The rim of a pulley, when cast, cools off very quickly, the arms and boss cooling later. This puts the arms in tension. With straight arms, fracture may occur unless the boss is bared quickly, or some other method adopted to reduce the difference in rate of cooling. To get some idea as to the amount of stress left in a pulley when cold, a casting of the dimensions shown in Fig. 6 was cast, with a runner on the boss. After dressing, the thin part of the rim was cut away on each side of that part of the rim which was attached immediately to the arms, as shown in Fig. 8. The diameter of this skeleton pulley was taken, by means of vernier calipers, across the line of each pair of arms in turn. The mean of the two was found to be 16.088 ins. Four pieces were then cut out of the rim, each midway between the arms, in order to break the continuity of that part of the rim, and allow the arms freedom to arrange themselves in line with their inclination. The diameter across the line of each two arms was again taken, and it was found that the mean of the two was 16.032 ins. This shows that the arms are held by the rim in a stressed condition.

Stresses in Pulleys.

A second pulley was cast with a runner, as shown at Fig. 9. This casting was treated exactly like the other. Before cutting the slots between the arms the mean of the two diameters was found to be 16.092 ins. After the rim was cut and the arms freed, the mean diameter was found to be 16.068 ins. When freed from the rim, therefore, the casting run on the boss contracted 0.056 in., whilst that run on the rim contracted 0.024 in.

Out of a batch of bought textile-machinery scrap, which had probably been in service ten to fifteen years or more, two small unbroken pulleys were taken, and treated in the same way as the previous cases. Both were 11-in. pulleys, but one had bent arms, whilst the other had straight arms. On freeing the arms from the rim in the case of the one with bent arms, a reduction in diameter of 0.04 in. was found, whilst in the case of the one with straight arms no reduction was observable.

The pulley with bent arms is always easier to produce with unbroken arms than one with straight arms. It is probable, however, that no cast-iron pulley ever goes into service quite free from unrelieved stress in the arms. The point to notice in the above experiments, however, is that the pulley cast through a runner on the rim left the least unrelieved stress in the arms. It is therefore wrong in principle to run such castings on the boss where it can be avoided.

In such circumstances in which a pulley is rejected for the slightest porosity in the boss, it becomes a serious question as to how to secure uniform soundness. Feeding the boss by rod gives very indifferent results. Fortunately, the problem is simple of solution. Such castings may be cast with almost unvarying success from the point of view of securing soundness in the boss by running on the rim, and having no riser on the casting. Running on the rim, therefore, justifies the two conditions which have been laid down. For a 16-in. pulley the runner section nearest the casting is $\frac{1}{8}$ in. by $1\frac{1}{4}$ in. For smaller pulleys a proportionate reduction is made. A number of pulleys made in the manner described are shown at Fig. 10.

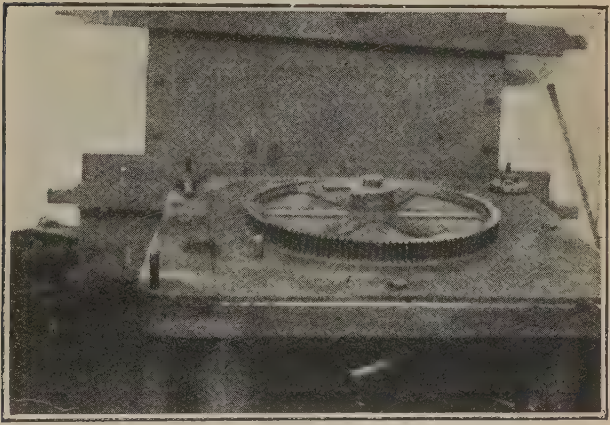


FIG. 13.

Gear Blanks.

The production of good gear blanks requires much care. The moulding of such wheels may be done entirely by hand or by the aid of machines. At Fig. 11 is shown a blank spur wheel pattern mounted on a jar-ramming machine. This machine will ram up any similar wheel satisfactorily. It will be seen that the arms of the wheel illustrated are much bent in the same direction as the line of the axis of the boss. In a case like this, the production of half patterns which shall register properly is a difficult matter. Here, however, an ordinary double-sided plate was made, but with a strong plate section of 1 in. The whole of the rim is on one side of the plate, the other side being straight, except for the centre containing the boss and hollow part which matches the arms. In the position shown at Fig. 11 the pattern is in position for ramming the drag parts. When the top parts are to be rammed, the plate is turned over. A wooden cradle (dimly seen at Fig. 11 behind the machine), heavily clamped at the corners, is put on the table of the machine, upon which the pattern plate rests solidly. The screws are put in and ramming proceeds. The

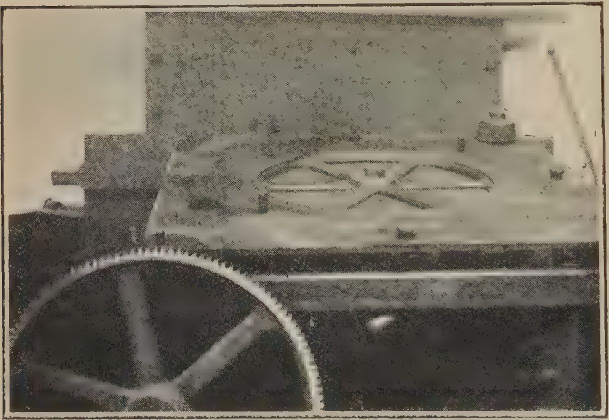


FIG. 14.

pattern ready for the top part moulds is shown in Fig. 12.

Wheels may be rammed by the hand or many kinds of machines. A simple wheel may be moulded quite well from one-half pattern. Where the teeth are cast, however, the rim can only be jointed at one edge. Consequently, two pattern plates are usually required for such wheels. Fig. 13 shows a method of using one pattern and stripping plates to make both halves of the mould. To ram the drag parts, containing the full depth of the rim and teeth, and half the arms and boss, the outer stripping plate is at its base, as shown in Fig. 13. The stripping plates between the arms are permanent. When the mould is rammed, the pattern is withdrawn downwards by a few turns of a handwheel underneath. To prepare the pattern for ramming the top part, the wheel pattern is brought up to its original position. The outer stripping plate is then raised, as shown in Fig. 14, reaching a stop when it is level with the top rim of the pattern. In order to secure proper register, the moulding box pins are placed on a line which divides the boss and two arms. A perfect joint can thus be secured. Many applications of this principle are possible.

Where a pinion with cast teeth is made on any kind of the small machines which have been described, it is a simple matter to make them on the same lines. Certainly, where the output required justifies, it may be an advantage to have different machines for top and bottom parts of such moulds, so that work can be proceeding on both halves at once, otherwise there is considerable advantage in the above method.

Two Pictures.

The making of really good gear blanks in cast iron is a difficult matter. Some time ago, at a meeting of the London Branch of the I.B.F., Mr. H. J. Young said that, a short time before, he had visited three works in which gear wheel blanks were made, the teeth being cut, and that there seemed to be no really good castings at all: in practically every case the teeth were more or less bad at the base. It is remarkably easy to get such results, yet with not a little care the results may be quite different.

In circumstances such as the author had to face, in which no gear casting is passed for service after machining if there is the slightest sign of porosity at the root of any tooth or in the bore of the boss, or on any machined surface, one has perforce to find methods of production which will give something like assurance as to the results.

There are few castings which are put to so severe a test at the hands of the machinist, who cuts deep gashes at close intervals all round the wheel rim, right into the heart of the cast section, leaving no place where a slight unsoundness might hide itself. The machining operations on a gear blank are of an expensive character, involving the facing up and boring of the boss, cleaning up the three rim faces, slotting the boss for the keyway and cutting the teeth. Before this last operation is begun the other machining operations are complete. If any defect only appeared when the cutting of the teeth had reached an advanced stage, the wheel was an expensive loss. Generally, the defects which had to be dealt with were:—(1) Those due to dirt on the top faces of the castings; (2) blow holes on upper faces; (3) sponginess in the bore; and (4) sponginess at the root of the teeth when cut. With regard to the first defect, the remedy is obvious. Good work on the part of the moulder is imperative. In green sand moulds there was often a tendency for plumbago to run before the metal, making dirty places. It is better, therefore, to leave plumbago off, particularly in wheels which were webbed. Dirt in a casting is often due to the insufficient size of the runner basin in relation to the size of the gates.

Limited Machining Allowances Unprofitable.

Blow holes may be due to faulty centre cores; too hard ramming of the mould (if green); insufficient venting; too much use of the swab; or dull iron. Whilst all these are certainly due to faulty work, it is true to say that the tendency to keep machining allowances down to $\frac{1}{8}$ in. on the upper surface of such castings is a very doubtful economy. Many a rejected casting would be in service if a little extra machining allowance were given on upper faces. Defects three and four are much more difficult to eradicate, being due to the reduction in volume in grey iron which takes place when the metal crystallises out from the liquid.

Figs. 15, 16, 17 and 18 show side views of a series of blank pinions as they stand on the moulds after casting. These relatively small castings can give a good deal of trouble, on account of the tendency for sponginess to appear in the bore and at the root of the teeth when cut all round the big diameter. Such castings cannot be fed solid with the rod. The casting shown at Fig. 15 can be had perfectly clean and solid if cast by a pencil runner through the small feeding head shown in the sketch, and if cast in the metal of the following order:—T.C., 3.4; Si, 1.5; Mn, 0.6; S, 0.08; and P, 0.4 per cent. The pinion shown at Fig. 16 will not yield good results by the same method owing to the greater mass where the teeth are to be cut. Completely satisfactory castings can be obtained by supplementing the practice as used in the first case by a series of chills, placed all round the castings in the region of the teeth, as shown. In this case, however, it is necessary to use a metal having a higher Si content, or the castings will not be machineable. The same procedure gives first-class results in the cases shown in Figs. 17 and 18, though the small feeding heads in these two cases are troublesome in fettling. One may note, in passing, that all these four castings could be quite satisfactorily cast in iron moulds.

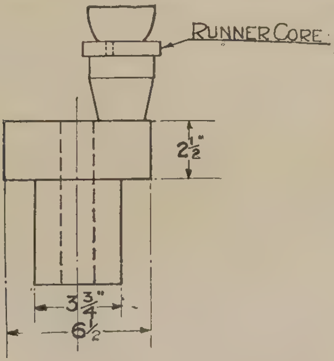


Fig. 15.

A series of pinions are cut from blanks, representative sections of which are shown in Figs. 19

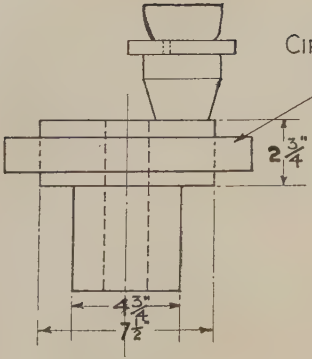


FIG. 16.

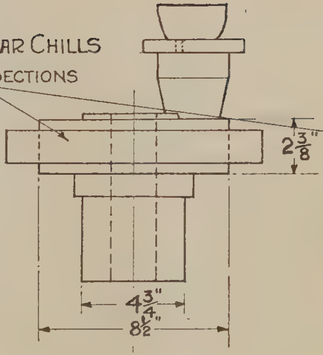


FIG. 17.

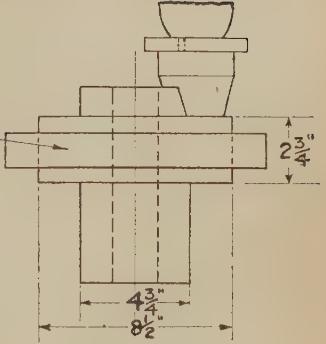


FIG. 18.

and 20. Many ways of running these castings have been tried. The method at present adopted, which gives very good results, is shown in the sketches. Two ⅜-in. runners are placed on the boss, around the under fillet of which a ring of chills is placed. No riser is used. Where castings of this character are made with a rim thickness of more than 1¼ in.

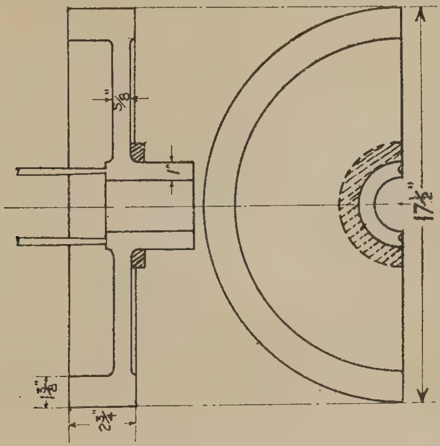


FIG. 20.

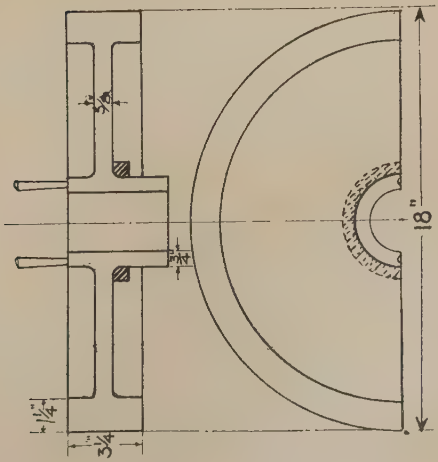


FIG. 19.

it is necessary to put a riser on the rim and feed it. Other wheels of the same general design, as Fig. 20, but with the lower part of the boss thickened to a $2\frac{1}{4}$-in. section all round, have a correspondingly heavier chill at that place. In this case, when the casting reaches the machine shop, a deep groove is first cut all round the base of the boss of the casting near the web, to provide tool clearance, after which teeth are cut all round, a single casting comprising two pinions being the result.

Spur Wheel Blanks.

Another type of blank is shown at Fig. 21, the mode of casting shown being the only one which will give assurance of a perfect casting. Teeth are cut all round the outside of the rim, the inside of the rim being cleaned up for a friction clutch.

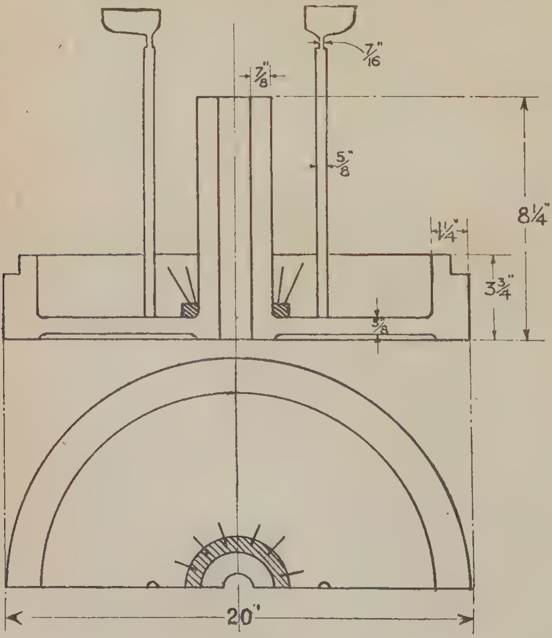


FIG. 21.

The long boss is bored and turned all down its length, whilst the bottom face of the casting is machined all over. It is run as shown through two 7/16 in. runners, with no riser.

A large variety of spur wheel blanks is made of the general design shown at Fig. 22. These are cast, with almost unvarying success, by means of one or two runners placed on the boss, and two

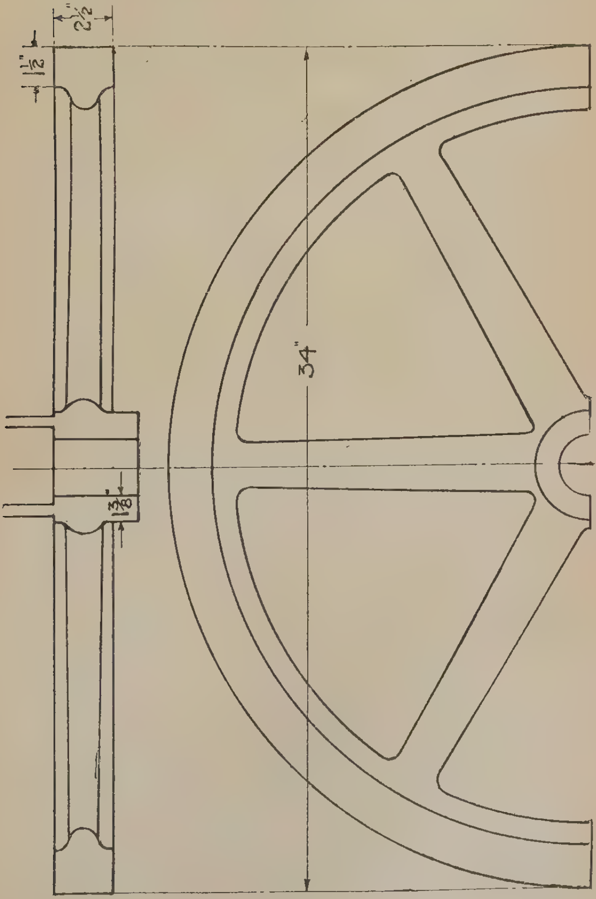


FIG. 22.

risers, one on each side of the rim. In this case, the runner is rod fed, and trouble never occurs at that place. For wheels of the size shown in the sketch metal of the order of GC, 2.9; CC, 0.5; Si, 1.7; Mn, 0.6; S, 0.08; and P, 0.5 per cent. is used, which gives easy cutting of the teeth for the tool, and perfectly solid and clear teeth all round the wheel. Wheels which have a greater rim sectional area than that shown at Fig. 22 are fed with the rod at two places on the rim.

The wheel blank, shown in section in Fig. 23, is of similar proportions to the last, but the arms

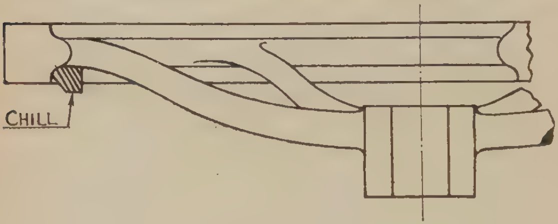


Fig. 23.

are bent as shown. This is the wheel which is rammed on the jar-ramming machine, as shown in Figs. 11 and 12. In moulding, it is found convenient to carry the hollowed joint caused by the bent arms in the top part. Consequently, when the mould is cast, there is a tendency for the rim to be robbed of liquid metal by the arms on solidifying, these being smaller in section than the rim, and lower. If no preventive steps were taken, porosity will appear on cutting the teeth at the junction of the arm with the rim. This is completely taken care of by placing a chill on the under side of each arm where it joined the rim, as shown in the sketch.

Conclusions.

To recapitulate; in webbed blanks, the use of a ring of chills round the boss wall give soundness of an order which cannot be reached in any other way. Whilst, however, in the case of the webbed blanks which have been referred to, such treatment of the boss is consistent with equal soundness in the rim (in which the teeth are to be cut) where deep teeth are required, necessitating a rim thickness in the casting of more than $1\frac{1}{4}$ in., then it becomes necessary to feed the rim by means of the rod. On the other hand, where a wheel has arms instead of a web, solidity in the rim may be expected up to an upper limit of rim section of $1\frac{3}{4}$ by $2\frac{1}{2}$ ins., without rod feeding on the rim, if the boss is fed by the rod. If such a boss is chilled, then the rim is likely to be unsound; the reason being that the chilling in the region of the runners shortens the length of time during which hot metal from the runners may gravitate through the arms, to make good the loss of liquid volume due to crystallisation proceeding in the rim. Where chills were used casting with highly superheated metal is unlikely to give good results, particularly if the runners are situated near the chills. In such cases the metal should not be poured until the " break " on the surface of the metal is fairly pronounced. Where no chills are used (apart from danger of scabbing) the hotter the better is a good rule, having regard to the upper limits of temperature which it was possible to reach in the cupola.

In the Paper a few apparently simple illustrations have been used. It would be a serious mistake, however, for any foundryman to under-rate their practical difficulties; yet careful observance of the principles here laid down will make it possible for him to avoid coming into the category of the dreadful examples quoted by Mr. Young, and machine shop rejections of 2, 3 or 4 per cent. will be the worst that need be expected.

DISCUSSION.

Mr. Laurie said that if one cast with only one small gate on a 16-in. pulley, the metal could not be more than $\frac{1}{4}$ to $\frac{3}{8}$ in. thick on the edge of the pulley. There was a chance that there would be unequal contraction. The metal also must be sufficiently hot on the other side of the mould. Mr. Longden had referred to the casting of blanks with a pencil runner. He took it that Mr. Longden was a believer in a pencil runner. He thought that some people made a fad of that. He had always understood that with pencil runners one discarded feeders, but Mr. Longden used both. In regard to putting feeders on the neck of the arm, his opinion was that if one did that and checked the liquid contraction there, it went on just the same. He thought it would be much better if the chill were taken away from the neck of the arm altogether, and the feeding done from the blank. He had once had to make a wheel of 14 ft. diameter. The wheel ran on a friction ring, and there was a hollow on the inside. It was not only a blank that they cast originally, it was really a toothed wheel. The result was that the point of the "V" came very near to the wall of the mould, and between each "V" was a heavy mass of metal. To feed each tooth was impossible. There were twelve arms. He fed as near as possible to the rim at the end of the 12 arms. To his dismay, when they came to machine the wheel they found soft parts at the root of the teeth. Could Mr. Longden tell him how the trouble might have been avoided?

Mr. Longden replied that it was a difficult problem, and he did not think he could offer any suggestions. With regard to the other things which Mr. Laurie had said, it was quite true that the shrinkage would be found somewhere in the arms. But what he was after and what he obtained was a solid rim when the teeth were cut. He believed in the pencil runner up to a point. It was effective up to a maximum sectional area of 1¾ in., after which it was useless. In regard to running pulleys on the rim, he had cast at least 6,000 pulleys in that way, and it was very seldom that he had one running thin on the opposite side. It did not need a very hot mould.

Mr. Hearst said that his method was to run pulleys on the boss. If one started running pulleys down the rim, and if the runner got just a shade to one side, they would probably find more scab on the pulleys than they generally found blow holes. In 95 per cent. of the cases the fault in a scrapped casting lay not in the making of the mould but in the running of it. In his opinion a pencil runner was better than any other kind. He ran down the boss and fed at the rim, and when they ran into the casting they used a deep, narrow cut.

Mr. Miller, speaking of belt conveyor pulleys, said that his people cast them down the boss, and they had very little trouble. At first they had some trouble because they cast two or three in the box, but now they cast them singly. Regarding the metal, he would like to know if Mr. Longden had ever experienced the trouble through having a chill on the face of the blank. Did the machine shop ever complain that they were too hard? Did Mr. Longden always aim at 0.5 per cent. manganese, or exceed that?

Mr. Longden replied that he had not tried higher than 0.5 per cent. of manganese. Regarding the other question, an iron with low silicon would stand less stress than an iron with high silicon. If the composition of the metal was controlled, together with a known depth of chill, no trouble was likely to occur. The cross sectional area of the chill should not be more than 80 per cent. of that of the section of the mould against which it was placed.

Birmingham Branch.

TRAINING THE YOUNG FOUNDRYMAN.

By T. Makemson (General Secretary).

Much that has been said and written about foundry apprenticeship appears to indicate that there is some confusion of thought with regard to the aim of the training. The training of the moulder has been confused with that of the foundry manager, and some writers appear to have no clear-cut ideas of the respective functions of practical and technical training. It is probably due to this confusion that so little real and lasting progress has been made.

Foundry workers are of two types, the workman, and the man holding a position of a supervisory nature. The kind of preparation required by the one type is not necessarily the same as that required by the other. The workman requires a practical training; the manager requires a much wider and more comprehensive outlook, which should, however, have a distinctly practical basis.

A system of foundry training should be aimed primarily at the training of thoroughly competent and intelligent workmen. It should also provide the necessary experience and advanced instruction to enable the more capable workman to prepare himself for promotion to the posts of foreman and foundry manager.

It is desirable that the higher ranks of the foundry trade should be filled as far as possible by men who have come up from the lower ranks. There will, however, always be a number of men in the higher ranks who have entered from other sources. It is not within the scope of this Paper to deal with the training of the latter type of man.

The Training of the Future Workmen.

The apprenticeship of most of the skilled workmen of the present and past generations consisted of spending a given number of years in a foundry, receiving their instruction from the foreman or from the workmen with whom they came in contact. There was usually little system in the apprenticeship, but the foreman or workmen took a real interest in the apprentices, and it must be admitted that craftsmen of the very first order were produced.

Conditions have now changed, and the present day foreman has a multiplicity of duties which were unknown to his predecessor of a few years ago; he is, therefore, unable to give the necessary time and detailed thought to apprentice training. Modern conditions make it more difficult for the workmen to devote much of their time to helping and instructing the apprentices, much as they may be willing to do so. Furthermore, in all but the smallest foundries, there is more or less specialisation, and there is, therefore, less opportunity for the apprentice to obtain a varied experience. All these factors necessitate some definite system or scheme of practical training in the foundry.

The foundry worker of the past had little necessity for even the most elementary technical knowledge. It will, however, be admitted that the conditions in the trade are changing rapidly, and it is necessary for the workman of the future to be able to perform simple calculations, to read drawings, and to have some appreciation of the physical properties of the materials with which he has to work. These requirements necessitate some elementary technical education in adition to practical training in the foundry.

A scheme of training must therefore be twofold—(*a*) practical, and (*b*) technical—and it should be definitely understood that the technical instruction is complementary to the practical and cannot supersede it to any great extent. It is true that the technically-trained apprentice will probably learn the practical work more rapidly, as he will be more intelligent and observant. There is no question, however, that the place to learn moulding is in the foundry and not in the school. The problem is to devise a scheme of training in the foundry which will produce a workman as capable as the workman of a generation ago who was trained by methods now obsolete.

There are two general schemes of systematic practical training, both of which are in operation in various foundries in this country, on the Continent and in the United States—(*a*) The apprentice spends the first two or three years of his apprenticeship in a "vestibule" shop or training shop before passing into the foundry; and (*b*) the complete apprenticeship is carried out in the ordinary foundry, but the apprentice spends the first two or three years under the close supervision of an instructor. These schemes will now be discussed in some detail.

The Vestibule or Special Training Shop.

This system has achieved some success on the Continent and in the United States, and one or two firms in this country operate similar systems. The shop is really a self-contained foundry, but is used entirely for training apprentices. In some training shops the apprentice works through a series of exercises, carefully graduated and designed to bring out certain features. At the end of a given time he commences to carry out work of a commercial character. Other firms eliminate the graduated exercises, or, at any rate, reduce the time spent on this kind of work, and the apprentice spends more of his time in the making of simple castings which would normally be made in the general foundry. Whatever may be the class of work on which the boy is engaged, he performs this work under the close supervision and under the instruction of instructors, and there appears to be little doubt that he does learn the elementary principles of the trade very rapidly, and that he quickly acquires a very fair degree of skill. The waste of time, which is very noticeable in the early years of most apprentices, is almost entirely eliminated.

The disadvantage of this scheme is that the instruction tends to be somewhat academic, and when the apprentice is transferred to the main foundry at the conclusion of his period in the training shop he finds that he has a certain number of things to "unlearn." Incidentally, some larger foundries have made very successful use of training shops for the short and intensive instruction of plate and machine moulders, but this application of the training shop is outside the scope of this Paper.

Supervised Instruction in the Foundry.

This is the more promising method, in that the boy learns to work on an economic basis from the very commencement of his apprenticeship, but he is definitely instructed how to do it, and he carries out his work under careful supervision of instructors. This method is really a modification of the old-fashioned apprenticeship, the difference being that the work of the instructor takes the place of the help which was previously given either by the foreman or the workmen when they had the time or the inclination. A period of two or three years is spent in this way. During the remainder of the apprenticeship, the boys are given an increasing amount of responsibility, and they carry out work either individually or in collaboration with the other apprentices or workmen. The instructors should still be available for advice and help, and it should be part of their duty to see that movements from one class of work to another are carried out as far as is consistent with the type of work done in the foundry with the state of trade.

This method appears to be the one which is most suitable for the foundries in this country. It can be applied, even in small shops, as it will be found that the supervision and instruction of a minimum of 8 to 10 boys are sufficient to employ the time of one instructor. In very small foundries, with only two or three apprentices it is impracticable to appoint an instructor, and it is suggested in cases like this that

> *The foreman should devote a certain amount of time to instructing the boys, or arrangements should be made whereby one of the workmen is specially appointed to carry out this duty.*

If it is understood that this workman devotes a prescribed period of time per day to this purpose, arrangements can be made to adjust the output of work expected from this workman, so as to take into consideration the time spent on instruction.

Whatever method of training is adopted, there must be a definite scheme, which should be drawn up only after the most careful thought. The scheme should give boys an opportunity to work as far as possible for some little time on every class of work carried out in the particular foundry, and there should be in existence a definite schedule which should show when the boy will pass from one type of work to the next. It should be the duty of the instructor to see that this schedule is kept as far as the state of trade in the shop permits, although naturally there will have to be some elasticity, as one can visualise a shop which at any given moment may be extremely busy in one department and may have absolutely no work in another section. It would be foolish to move the boys to the latter section from another, because his schedule says he should go there on a certain day. It is obviously desirable to let him stay in the old section for a short time until the new department is able to provide him with sufficient work to keep him busy.

Typical schedules of the apprentices' training are those which are operated by Metropolitan-Vickers Electrical Co., Ltd., of Manchester.

Technical Training.

The scheme of technical training should be directed to imparting the elementary technical knowledge which is necessary to enable an intelligent workman to understand the principles underlying the trade, but it should be sufficiently broad to form a basis for more advanced instruction for those boys who are found capable of deriving benefit from it. In other words, technical training should be conducted with the moulder in view, but it should be broad enough to form a basis for the training of the future foundry manager.

The arrangement of a scheme of technical training necessitates consideration of several matters. It is necessary to decide whether the classes should be held in the day-time or in the evening; whether they should be conducted by the local education authority, or by the employer, and whether attendance should be voluntary or compulsory.

The ideal form of technical class is one held during the day-time by the local education authority, at which attendance is compulsory. Unfortunately, this ideal is very difficult to attain. The advantage of classes in the day-time is that the apprentice is fresh. The objection which has been frequently raised to day-time classes, namely, that work in the foundry would be interfered with, has been shown by experience to be groundless, as very little disorganisation takes place. Classes held by public authorities are recommended, because they make possible the attendance of apprentices from several works, and the larger numbers permit of the division of the classes into grades, elementary, intermediate and advanced, etc. Several firms are convinced of the advantages of day classes, and in default of the classes being provided by the local education authorities, are conducting the classes themselves in their own works and at their own expense.

The author realises that under present-day conditions the establishment of a number of day classes in various parts of the country is very difficult, as employers, as a whole, are not yet convinced of their advantages, and are concerned about the apparent disorganisation which they think takes place, and the expense of paying the employees' wages. At the present time, therefore, most employees have to be content with attendance at evening classes, and it is hoped that this Institute will arouse sufficient interest among employers and employees to induce a larger number of apprentices to attend the classes which already exist in many parts of the country, and also induce education authorities to establish other classes in addition to those in existence at present. It is perhaps hardly fair to enforce compulsory attendance at evening classes. The employer should, however, give encouragement to his apprentices to attend. Suggested methods of encouragement are the granting of time off on the evening of the classes without loss of wages, and a small reward for successes, either in the form of increased wages or a prize. The knowledge that success in evening classes will be taken into consideration in connection with promotion is perhaps the most valuable kind of encouragement.

Suggested Curriculum.

The following is a suggested scheme for classes in foundry work. This scheme is suitable for either day or evening classes, conducted either in schools managed by the local education authority or in works-schools managed by the employer:—(1) Revision of elementary school work in arithmetic, mensuration and general science; (2) elementary machine drawing and sketching. It is of much more importance that a foundryman should be able to make good sketches than is generally imagined. The fact that many excellent craftsmen do not possess this accomplishment is no reason why it should not be possessed by the next generation of foundrymen; (3) detailed lectures on the underlying principles of foundry practice, *i.e.*, runners, risers, venting, properties of sands and the many other practical details which have a scientific foundation which is too frequently misunderstood; and (4) *Foundry Metallurgy.* This should include some account of the manufacture of pig-iron, the influence of the constituents of iron upon its properties, and an elementary study of furnace design and cupola practice.

Pattern Makers.

The course to be followed by apprentice pattern makers should include the following:—(1) Revision of elementary school work in arithmetic and physics; (2) drawing and sketching; (3) patternmaking materials; contraction; use of prints; loose pieces, drawbacks, etc.; methods of pattern construction; and (4) complete instruction in methods of constructing and laying out patterns and coreboxes for representative jobs; making boards for loam moulding and patterns for plate moulding.

In all this work attention must be given to foundry requirements, and in considering any job the method of moulding the job should always be discussed. It is desirable to devote a few lessons to the purely metallurgical side of the foundry in order to widen the outlook of the apprentice.

Promotion Work.

It is essential to any scheme of practical and technical training that it should provide an opportunity for boys possessing more than average ability to qualify themselves for promotion to the higher ranks of the foundry trade. It is suggested that when boys reach a given age—say 19 or 20—the employer should endeavour to ascertain whether they are likely to be able to take advantage of more advanced training. At this age, most promising boys will have given some evidence of their promise. They should be selected for promotion on account of their practical knowledge and the ability which they have shown by their work in the foundry, and also on account of their technical work, which can be judged from the results of the school examinations.

Boys so selected should be given an opportunity of carrying out some more advanced work in the foundry. They should be given experience on the cupola and should also spend some little time in the testing and chemical laboratories and in the costing department. The details will, of course, depend upon the facilities existing in the particular works.

The technical training of the selected apprentices should consist of metallurgy, foundry engineering and foundry organisation. At present there is a considerable difficulty in acquiring advanced technical instruction suitable for the foundry industry, as it is only in a very few centres that such instruction is given and it is improbable that it will ever be possible to conduct advanced foundry classes in more than a few industrial centres. It is this difficulty which forms a very strong argument in favour of the establishment of some kind of foundry college or technical high school similar to the very successful school presided over in Paris by M. Ronceray. Whilst it is realised that there are some disadvantages in a college of this kind, yet there does seem to be room for the establishment of a modification of the French scheme, either as a separate college or as a department at one of the technical colleges or universities. It is probable that the latter suggestion is better than the establishment of a separate college.

Apportionment of Costs.

The degree to which the scheme is developed will depend to a large extent upon its cost and upon the possibility of receiving returns on the financial outlay in the direction of improvement in the personnel.

(*a*, *Practical Training.*—The cost of the practical training should undoubtedly be borne by the employer. The cost will be comprised principally of (*a*) the wages of the apprentice during the first part of his apprenticeship before he becomes of economic value to the employer and (*b*) the salaries of the instructors. It is well-known that the apprentice usually spends the first year or two of his apprenticeship in work which is definitely of an unproductive nature, and in many cases he barely earns his wages. An organised training scheme will have the effect of making the apprentice justify his wages at an earlier age and will, therefore, be a direct saving.

The second charge—that of the instructor's salary will undoubtedly be saved by the increased producing power of the apprentices working under his guidance. It can therefore be taken as practically certain that an organised scheme of practical training will actually be a paying proposition rather than a charge, on account of the increased productivity of the apprentices.

(*b*) *Technical Instruction.*—It is obviously the function of the local education authority to provide the technical classes in foundry practice. Complaint has frequently been made that the authorities are luke-warm and the small number of foundry classes which are held in various parts of the country are taken as a sign of the neglect. Undoubtedly, some education authorities are distinctly unhelpful, but the scarcity of foundry classes is probably due to lack of demand rather than to lack of enterprise on the part of the people responsible for their organisation.

A national training scheme in which technical training is an integral part will necessitate the extensive establishment of classes, and there is little doubt that when the education authorities are convinced that the demand exists, they will be willing to do all in their power to supply it. Many classes have died out through lack of support from the very people for whom they were intended. Training schemes will attract a better type of boy into the foundry, who will realise that the attendance of classes is a definite part of his training and there is little doubt, the classes will then come into existence.

In some parts of the country, foundry classes are being organised under the auspices of more or less informal advisory committees, which consist largely of members of this Institute. It is suggested that in every centre where such classes are found to be necessary, the members should themselves approach the local education authorities and if possible, act as local advisory committees.

An important feature is the type of man selected as teacher. It is not necessary to have a foundryman to teach drawing, mathematics, etc., but foundry practice, foundry organisation, etc., should certainly be taught by a man of wide foundry experience and advisory committees can help considerably in the selection of teachers.

Private Classes.

There are several large firms in this country and in America who have organised their own trade classes at their own expense, thus avoiding the necessity of their apprentices attending the local technical classes. Such schools are usually held in the day time in the employer's works. The apprentice leaves his work for a prescribed number of hours per week and attends the classes. The whole of the expenses of such schools including the boys' wages while he is at school are borne by the employers. Most employers who operate such schools believe that the expense is justified as a business proposition. So convinced are they of the value of the elementary technical training to their apprentices that they organise it and pay for it themselves in default of suitable classes held under public auspices. The objection which is frequently urged—that attendance at the day schools interferes with the regular routine of the foundry—is found to be one which can be easily avoided by suitably arranged times of the classes. It is very often difficult for a boy to leave the foundry at a given time in the afternoon when casting is proceeding, but several foundries find it quite easy to release their boys for two or three hours per week in the mornings.

The financial responsibility for the advanced technical training naturally rests upon the governing body of the particular college at which the training is given. Government grants would be given, although there should be a large number of scholarships, some of which would probably be provided by the generosity of members of the industry. The governing body of the college arranging such courses would also expect, and would be entitled to expect, assistance from the industry in the provision of laboratory apparatus and equipment.

Financial Considerations.

The schemes of training, such as have been outlined, do undoubtedly impose financial responsibility upon the industry, and it is realised that the present time is a very difficult one financially. There is little doubt, however, that money spent on training the future personnel of the foundry should be treated in the nature of an investment. In times of normal trade there will be a definite shortage of skilled moulders, and even now there is undoubtedly a shortage of men trained on modern lines to fulfill the responsible positions. The gain to the industry will more than repay the cost in a few years' time.

It is found that some enlightened employers refuse to embark upon a training scheme because they fear that when once trained the apprentices will drift to the works of another employer, who will get the benefit of their training. This fear, whilst a perfectly natural one, is shown by experience to be groundless. Naturally, men who have completed their apprenticeship do pass along to other firms, but in very many cases they come back again to the original firm, and are all the better workmen for having had a little outside experience.

National Certificates.

A number of foundry classes are at present in successful operation in various parts of the country, and certificates are issued on the examination results. These certificates are granted by various provincial examination bodies, such as the Union of Lancashire and Cheshire Institutes. It has recently been pointed out in several quarters that there is no uniform standard for these certificates, and that a certificate granted in one district carries little weight in another. At present the examinations upon which these certificates are given deal with fairly elementary technical work, such as is found to be necessary to the intelligent moulder. The lack of a national certificate for work of this kind is perhaps not a serious disadvantage, as the moulder is generally judged by the work which he produces in the shop and not by some certificate which he holds. There is, however, a distinct need for some kind of foundry certificate of an advanced character suitable for the man who hopes to hold a position of responsibility in the trade. The holding of such a certificate will not guarantee that he will successfully manage a foundry any more than the holding of a medical diploma will guarantee that a man is successful in the treatment of disease. Success demands qualities of character in addition to knowledge, but it does demand the knowledge, and the certificate would be a guarantee that the holder possesses the requisite knowledge.

In the professions of mechanical, civil and electrical engineering, the national professional qualification is the associate membership of the respective institutions connected with those professions. A university degree in engineering generally exempts the candidate from the associate membership examination. In other cases, the diploma of certain colleges exempt the candidate from certain portions of the examination, and require that he shall pass the examination of the respective institutions in certain sections only, before receiving his associate membership.

This consideration leads to the conclusion that sooner or later it will be the duty of this Institute to formulate and conduct some kind of examination. It will be impossible for many years to make membership of the Institute dependent upon passing such an examination, and such a course is not suggested. The existence of the examination would, however, increase the prestige of the Institute and of its members, and the examination certificate would be the national certificate in foundry practice.

The technical colleges would either prepare candidates for this certificate, or, alternatively, certain technical college examinations which reach a standard set by the Institute would exempt the candidate either from the whole or from part of the examination.

The whole question of apprenticeship has recently been referred to one of the Committees of the Institute to examine, and it is hoped that eventually recommendations will be made which will have a far-reaching effect upon training for the foundry industry.

Conclusions.

To summarise the proposals which have been made, it is recommended that a scheme of training should be devised on the following basis:—(1) Apprentices should be trained in the foundry under capable and experienced instructors appointed for the purpose; (2) that apprentices be encouraged to attend classes in elementary mathematics and drawing, and that local education authorities be encouraged to form classes in the rudiments of foundry metallurgy. Where it is found impossible to arrange such classes the formation of works classes conducted by the employer is recommended, and (3) selected apprentices should be given special training in the works and facilities to attend advanced classes.

It is realised that these proposals necessitate financial outlay, but there is little doubt that such outlay is justified and will be found to be a profitable investment. The present shortage of apprentices and the lack of facilities for training them properly are very serious problems. Any reasonable expenditure on proper training facilities is amply justified, and it can be taken as certain that when the training problem is solved boys will be attracted to the industry in greater numbers. When boys and their parents realise the opportunities that are present in the foundry industry, and when they realise that the boys will be properly trained to take advantage of these opportunities, then the shortage of suitable candidates for the foundry will be a thing of the past.

DISCUSSION.

The Branch-President (Mr. F. G. Starr) remarked that the great difficulty at present was to get the right type of boy; most of the boys wanted to enter the machine shop. There was also a difficulty in securing an instructor who was also a skilled craftsman able to exercise proper control. The problem of boys being allowed to attend school classes could, however, be overcome without much inconvenience in the foundry. Mr. Makemson had, he considered, given an outline which formed a good ground work to start on.

DR. F. JOHNSON, of Birmingham Central Technical College, stated that the Birmingham Education Authority was anxious to do what it could to promote foundry training, and could not understand why the matter had not been taken up more energetically by the leaders of the industry. They could guarantee to provide all the technical instruction that was asked for, whether day time or evening classes were desired or both, provided a suitable scheme had the backing of the industry and a sufficient number of students was forthcoming. While compulsory attendance was satisfactory from an organisation and budgeting point of view, voluntary students were preferable, because they made the teaching more interesting and effective. However, compulsory attendance in the long run caused the students to desire an improvement in their status, and converted them to voluntary attendance at classes. A central college, as at Paris, was hardly the sort of thing to start with, though it might be an ideal for the future. Local efforts should first be made, leading up to a central body or college, where either a degree or national certificate could be obtained. The money required in different localities would not be large, as local authorities in large industrial centres already had the accommodation and could find the requisite staff. A local advisory committee was needed to set the ball rolling, and in Birmingham the Education Authority would be ready to co-operate with that committee. The observations and suggestions of Mr. Makemson showed him to be a man with a wide grasp of the difficulties involved, having an appreciation of the possibilities of the situation and a knowledge of the sporadic attempts already made to overcome the lack of facilities for the adequate training of foundry employees. He was glad to hear that the Institute was earnestly engaged in considering a scheme for the provision of greater facilities.

Apathetic Employers.

Dr. Fisher, Principal of the Wolverhampton Technical College, described Mr. Makemson's survey of the problem as admirable. He agreed that the right place to learn foundry work or fitting was in the shop. Nevertheless, all their experience indicated that it was desirable, and indeed necessary, inside their technical college to have workshop facilities of some kind, for without it there was no common ground between the teacher—no common ground to which the lecturer could refer—and the students drawn from diffenent places and doing different kinds of work. After all, it was not possible to experiment in a factory, and some provision was really needed for practical work in the college. He endorsed Dr. Johnson's view that local authorities were willing to provide the training required, and that the overhead expenses would be already met, as the necessary accommodation would be available. In Wolverhampton they carried on a foundry trades junior school which would have been closed down but for a recognition by the authorities of its importance; happily, it was now gradually growing, despite the apathy of employers. It was not a mere continuation school, and through a system of information and interviews, when boys left school more lads had been induced to enter for foundry work. These lads did experimental work with the materials of their industry directed to the problems of the foundry, and the instruction was designed to fit them for a senior course in the technical college.

An Experimental Foundry.

Mr. Flavell mentioned that the Principal of the Technical School at West Bromwich had persuaded the Council to provide an experimental foundry. In the Midlands the apprenticeship of boys was not carried out sufficiently thoroughly. A condition of employment at his factory was that a boy should attend classes. He suggested that employers and heads of departments should try to understand the psychology of their boys. Boys wanted encouragement, and employers should interest themselves in the lads while they were at work. In order to get boys to use their brains it was a good thing to depart from stereotyped models and methods from time to time. The more interest employers took in their boys the better the class of lad they would get.

Mr. Rutland, speaking as Principal of the Engineering Department of the Wolverhampton College, in agreeing with Mr. Flavell, said no definite models were made at his classes. Every job was a job, and there was variety to interest the boys. There were no exercises as such.

Mr. Wilkinson considered there should be no difficulty in obtaining suitable instructors. His own experience was that every one of the lads under training and on piece work earned his wages, and made more money for the firm than if the castings made had gone through in the ordinary way. "You can develop good craftsmen if you take an interest in the lads," said Mr. Wilkinson, in pointing out that the objection of some employers to giving such training—that young fellows would leave a firm after having received tution—cancelled itself, because young foundrymen in other works would also desire a change, and so the position would right itself. Further, if a new employer could afford to pay an increased wage, surely the old employer could do so. Nevertheless, it was undesirable for a young man to get into a rut, for obviously if he moved about he gained wider experience. If in the foundry they taught a lad to make castings well and quickly, and paid him for it, he would advance himself and become highly efficient; and if they could at the same time extend the facilities for technical training, by all means do so. The lack of skilled men was because boys were "put in a corner," and consequently had to pick up knowledge of their work anyhow. A capable young man who would have a natural sympathy with lads should be placed in charge of them; they should be provided with different kinds of work from time to time; and, given encouragement, he ventured to say that they would make good progress. The solution of the trouble in the foundries lay in their own hands; they only had to take a moderate amount of care and interest in the training of these boys, and believed from his own experience that they would respond.

Lessons from Wasters.

Professor Hanson (Birmingham University) thought there was a need for small foundries at technical colleges where they could practice in a small way some of the things done in industry, but not with the object of making castings. The real reason was so that the students could see what happened when the metal melted and solidified. As a previous speaker had said, the students learnt a lot more when a bad casting was made, because the faults could be pointed out and the causes investigated. Such facilities enabled the teacher to give instruction on what to avoid and how to avoid it, and to explain the cause of faults and so forth.

Mr. Greenway, speaking as one who had gone through his apprenticeship, made several suggestions, and in commenting on pattern making urged that it was necessary to obtain an inside knowledge of machine moulding.

In reply, Mr. Makemson said that present facilities were scattered, and some co-ordination was required to get the boys into actual touch with these various schemes. He agreed that the problem lay more inside the foundry than with the technical school. His own experience of training apprentices was that it was a paying proposition. Boys wanted to do something useful. Odd jobs and errands took away their enthusiasm, which they ought to encourage. A foundry in the technical school was not essential perhaps, but it was extremely useful for pointing out defects. Every scheme of training should be definitely practical and have a commercial aspect.

Sheffield Branch.

THE TEST-BAR PROBLEM AND SOME RECENT DEVELOPMENTS.

By J. G. Pearce, B.Sc. (Eng.) M.I.E.E. (Member).

The author apologises for raising again a problem which has been constantly before the ironfounder in one form or another. Founders are all familiar with the kind of difficulty which cropped up when an engineer specified a test bar which gave, perhaps, 12 tons tensile for a casting which, when cut up, showed only about 7 or 8 tons tensile. The problem of securing a test bar which would accurately define the mechanical properties of the metal in the casting is one of the most difficult the industry has to face, and is not easily solved. Some recent developments, however, had taken place which, in the considered opinion of representatives of the industry, would ensure a closer approximation in properties between test bar and casting than had hitherto been possible. The recommendations were embodied in the new specification about to be issued by the British Engineering Standards Association, in preparing which a Committee of both makers and users had co-operated for the last two or three years. The original proposals were issued in tentative form by the Institute of British Foundrymen, and the Cast Iron Research Association had subsequently shared with it the experimental and committee work in the production of the specification. The work involved had been enormous, and the industry could congratulate itself on the first general specification for cast iron of a national character which had ever been issued. In that achievement Sheffield had played a considerable part, and the names of three members of the Sheffield Branch had been prominent throughout the work. Mr. John Shaw, of the Brightside Foundry and Engineering Company, Limited; their President, Mr. J. T. Goodwin, of the Sheepbridge Coal and Iron Company, Limited; and Mr. J. R. Hyde, of

Robert Hyde & Son, Limited, had been especially prominent.

The design of a casting is based on the strength of the material, but this cannot ordinarily be checked by testing the casting itself. It is necessary to make the test by an additional test bar. Most tests specified by engineers assumed homogeneous material, but in cast metals the crystalline structure at the mould face, where the metal cooled most rapidly, is different from that in the interior of the casting, where the metal cooled most slowly, and the change is progressive. In cast iron there is the further complication that graphite is deposited on cooling, the rate of which governed its size and distribution. It is, of course, absurd to suggest test bars for some castings, such as a chilled roll or an ingot mould, but most engineering castings are purchased to a specification prepared by an engineer, and mechanical tests are inevitable. One of the commonest difficulties of makers of engineering castings to-day is the knowledge of lower export weights, and hence of freight rates and prices, of American and German material compared with British.

Subject to tests being metallurgically sound, anything which contributes towards ease of making, cheapness of preparation, and simplicity in testing and interpretation will foster the scientific control so urgently needed to-day. The B.E.S.A. Committee responsible for the new specification had borne in mind both the metallurgical desirability of the tests recommended and their practical convenience, and it is hoped that not only will the specifications be used, but that foundries will make a point of being prepared to meet them. In particular it is desirable that other test bars in B.E.S.A. specifications for particular castings, such as pipes, automobile cylinders, etc., should no longer be applied to general castings.

Shape of Test Bar.

Discussion has always taken place over the best shape of a cast-iron test bar, whether it be square, rectangular, or round. Ease in machining demands a round test bar, but the merits of the various shapes must be considered first of all from the metallurgical point of view. Clearly a square test bar should be stronger than a round test bar of diameter equal to the side of the square, on account of the larger area of metal, but *per unit area* it has always been found from experience that the round bar gives a somewhat higher strength than the square bar. Whether this difference is due primarily to a casting effect due to mode of solidification or to a testing effect due to the distribution of stress across the bar has been uncertain, but tests recently made in the C.I.R.A. Laboratory by Dr. A. L. Norbury throw some light on this point. A group of round bars was made; some of these were machined square before testing, and some were machined round. Similarly a group of square bars was cast; some were machined round and some were machined square before testing. Results showed clearly that the round bar is stronger than the square bar, even when made from a bar originally cast square, and that the square bar is weaker than the round bar even when made from a bar originally cast round. In a bar cast square, the crystallisation gives a corner effect, which we always endeavour to avoid in actual castings, hence we believe it should be avoided in test bars. In a round bar the crystallisation is radial and uniform; in a square bar the corners tend to freeze more quickly than the interior of the bar and there is a lack of homogeneity. The round bar is, therefore, to be preferred.

The influence of machining has also to be considered. Tensile tests inevitably have to be made on machined bars, but in the case of the transverse bar it is invariably tested without removing the skin. The influence of machining depends on the character of the iron in the bar. In the case of an ordinary grey iron, the more rapidly cooled metal on the outside is the strongest, and hence machining results in a lower test value. The skin, however, may contain minute surface fissures, which result in an early fracture under load, and the one effect may offset the other. It should be remembered also that there is a tendency for measurements of a cast bar to be greater than is actually the case, and this may give a slight advantage to the machined bar. The result of machining, however, is not predictable in advance. It may improve or it may worsen the test. If deflection is wanted, the bar should be machined If stiffness (high breaking load) is required it should be tested as cast.

Sufficient has been said to show why the standard bar should be cylindrical. In the case of the transverse bar, it is preferably tested without machining on account of the expense involved. The next question is: How shall the test bar be taken?

Cast-on versus Cast-off Test Bars.

Ordinarily it is not practicable to test the casting itself, although this may be, and frequently is, done for small castings and castings which have to withstand pressure. Furthermore, in ordinary cases it is not practicable to cut the test bar from the casting. For certain large and important castings heavy ring risers are present, and test bars may be, and frequently are, cut from these parts. Ruling out these possibilities for general use, two alternatives remain. In the one case a test bar can be cast an an integral part of the casting, a condition which is described as "cast-on." In the other case the bar can be cast entirely separately from the casting, but from the same ladle of metal at the same time as the casting is made. This condition may be described as "cast-off." In the past, engineers have specified the cast-on bar, as the presence of the bar on the casting is an implicit guarantee that it was cast from the same metal at the same time. This procedure, however, has frequently resulted in the engineer acting against his own better interests, as the founder tends to concentrate on making a good bar rather than on a good casting, and very careful specification indeed is required for a cast-on bar. If a foundry is run under what might briefly be described as A.I.D. conditions—conditions to which every first-class foundry should aspire—the separately-cast bar can be shown to have decided metallurgical advantages.

The controversy between the advocates of these two types of bars is often taken to be one between that school which desires to test the casting itself, and that school which desires to test the metal of the casting. This assumes that the cast-on bar does not in fact test the casting, but it does so if one condition is observed; if there is a relation between the section of the test bar and the section of the casting. If a casting has a varying section it is difficult to see how any single bar can truly represent the casting itself. In point of fact no single bar, which is essentially a casting of uniform section, wherever and however cast, can represent a casting varying in section. If the test bar is cast on the casting then the problem of what the test bar really represents is complicated by the proximity of the casting itself. It will be evident that so far as the composition is concerned, it is immaterial whether the test bar is cast-on or cast-off, but the strength of a test bar is affected by two things—composition and rate of cooling. In the case of a cast-on bar the natural or inherent rate of cooling of the bar itself is complicated by the rate of cooling of the mass of the casting, and is affected according to the way in which the test bar is placed with respect to it—that is laterally, longitudinally, top, middle or bottom. The question of distance between the casting and the bar also comes in. Comparison between the results from cast-on bars is impossible. Experience may enable a cast-on bar to be so placed and dimensioned that it does in effect give a strength similar to that of the casting, but such cases must be very rare.

The logical procedure, therefore, is to cast a bar from the same metal at the same time as the casting proper, but in a separate mould—in dry sand for dry sand and loam castings, in green sand for green sand castings — thus excluding variations due to the proximity of the casting itself. With such a bar it becomes possible to compare the results from different foundries and from the same foundry on different days. In fact an automatic criterion of foundry progress becomes practicable. With respect to the dimensions of the bar clearly some relation must exist between the section of the test bar and the average section of the casting. Thus, it would be useless to represent a large casting of hard metal with a small bar which would come out white from the mould. It would be equally useless to represent a $\frac{3}{8}$ in. thick light casting of soft metal by a test bar of heavy section. The standard sizes of test bars, however, are affected by purely practical considerations. The exigencies of standard testing procedure do not permit a large number of bars, but in the British Engineering Standards Association specification at least three are recommended. A test bar has so much greater mass than even thin castings, that the smallest test bar must be well in excess of the thinnest castings usually made. In point of fact it is not satisfactory regularly to cast bars less than 0.875 in. thick, and this is the diameter of the smallest bar in the specification. It is taken as representing castings up to $\frac{3}{4}$ in. across the main section. Very heavy castings cannot be represented by too big a bar, as the breaking load must be within the limits of ordinary testing machines. The largest bar recommended is, therefore, 2.2 in. diameter to represent castings whose main section exceeds 2 in. Castings whose main cross section varies between $\frac{3}{4}$ and 2 in., and which probably comprise the bulk of ordinary engineering castings, are represented by a bar 1.2 in. in diameter. This particular size is not only a convenient casting size, but is chosen with regard to possible international agreement. The American standard so-called arbitration bar, which for many years has been $1\frac{1}{4}$ in. in diameter, has been reduced to 1.2 in. in conformity with the B.E.S.A., and the standard German bar has a diameter of 30 mm., which is the same thing. Furthermore, in 1913 the International Association for Testing Materials got as far as agreement on a standard cast-iron bar 1.2 in. in diameter with 18 in. supports.

We thus begin to see the foundations of a national agreement on the methods of testing cast iron. Any grade of metal—and there are two at present covered in the specification—can be provided for by a cast-off bar in one of three standard sizes, according to the average section of the casting represented. The engineer may specify either tensile or transverse tests, or both, and the tensile pieces are machined to a standard B.E.S.A. diameter; the transverse pieces are tested at distances between the knife edges, which will give an easily measurable deflection with a breaking load within the capacity of an ordinary transverse machine.

The adoption of these standard bars promises to have a considerable influence upon the development of cast iron. The number of variables entering into the production, both with respect to the raw material, the melting process and the moulding process, are so great that it has hitherto been impossible to correlate the results of commercial testing in a rational manner. We may shortly be in a position to predict what mechanical properties the standard bar should yield from a given composition. We may now proceed to consider the respective merits and demerits of the tensile and the transverse test.

Tensile Test.

From the founder's point of view the tensile test has several acute disadvantages:—(1) To ensure fracture the test bar must be machined below its cast size, and the strength is, therefore, measured on a weak and slowly cooled core. This makes it difficult to deduce a proper relationship between tensile and transverse from ordinary commercial results; (2) the cost of machining has to be met, and the tensile testing machine is relatively complicated and costly; and (3) the test is particularly susceptible in cast iron to non-axial loading, and yet really satisfactory provision for ensuring axial loads is seldom found. These objections are purely practical, but there are in addition some theoretical considerations:—

(4) The figures the designer really values from the tensile test are yield point and elongation. In ordinary cast-iron testing the ultimate breaking strength is the only figure obtained. The metal is assumed to have no ductility, and the tensile strength is measured on the original area. No gauge length is marked. The test therefore fails to differentiate a brittle from a tough iron in spite of the fact that the former may have a high, and the latter a low, tensile strength, accompanied by a small elongation; and (5) there is also the theoretical question as to how far a direct pull is a suitable test for an aggregate like cast iron, so seldom used in direct tension, and consisting of a steel-like matrix, broken up by patches of brittle phosphide and graphite.

These disadvantages might be considered sufficient to condemn the tensile test for cast iron. Provided, however, they are appreciated and understood, both among engineers who specify and inspectors who conduct tests, there appears to be no reason why the test should not be retained. Many works having foundries are equipped with tensile testing machines and the technique of the test is fairly well understood. Few foundries without machine shops are equipped with tensile machines, and there is great need for a cheap and reasonably accurate tensile machine for foundry use.

It should be particularly noted that the errors in results due to mistesting cast iron in tension are at the expense of the material, and hence of the maker, as the figures are always lower than what might reasonably be expected.

The Transverse Test.

The transverse test is a much older test in the foundry than the tensile test, and is much more popular. The bar can be tested without machining, and the machine is, as a rule, simple, cheap, and easily manipulated. The figures for breaking load and deflection are easily understood and comparisons are simple. A proper appreciation of the few drawbacks of the test would make it even more valuable than it is.

(1) The first disadvantage is the multiplicity of the types of standard bar in use. Dealing with the smallest first, there is the ½-in. square bar introduced by Keep, tested at 12-in. centres, very popular in light foundries. The Admiralty bar is 1 in. square, tested at 12-in. centres. The standard B.E.S.A. pipe bar is 2 in. by 1 in., tested at 36-in. centres. It is hoped that these and other transverse bars will be completely superseded by the three bars mentioned above, of which the 0.875-in. bar is tested at 12-in. and the 1.2-in. and 2.2-in. bars at 18-in. centres.

(2) The second main disadvantage of the transverse test lies in the large variation in result which occurs with small variations in bar dimensions. The disadvantages are acutely felt when transverse test results are given with the nominal as distinct from the actual bar sizes. In a round bar the breaking load varies inversely as the cube of the diameter. Since it is practically impossible to cast a bar exactly to the nominal dimensions, it

is essential to measure the bar dimensions carefully and correct the breaking load before any accurate comparisons can be made. This difficulty might be overcome if it became general to express the result of the transverse test as modulus of rupture instead of breaking load.

Modulus of Rupture.

An ordinary transverse test is an end-supported centrally-loaded beam. If the supports are L in. apart, and the load at the centre W lbs., the bending moment by ordinary beam theory is $\frac{WL}{4}$ The resistance offered by the beam depends upon its size and shape, and may be expressed as fZ, where f is the resisting stress set up per square inch of the beam section, and Z takes into account the size and shape of the section. For a given bar it is a constant known as the section modulus. Within the elastic limit $fZ = \frac{WL}{4}$ If the bar is tested to destruction the formula ceases to be strictly true, but it is convenient to measure the stress at the point of fracture f as $\frac{WL}{4Z}$, and f becomes the modulus of rupture. If a bar is standard $\frac{L}{4Z}$ is evidently constant, which can be worked out. Thus, for a 1-in. square bar tested at 12-in. centres $f = 18W$, and for the 2-in. by 1-in. bar $f = 13.5W$, where f is in tons per square inch and W is in tons. For bars cast accurately to size the conversion is simple.

This, however, only applies when the bar is absolutely standard size, which is very seldom the case, and in the specification a variation is permitted on any diameter of plus or minus 0.1 in. Bars under this size have to be scrapped, but over it they may be machined to size. Fig. 1 shows for the 1.2-in. bar the lines which would give rupture moduli when breaking loads are known for bars above or below the standard size. The striking difference in modulus of rupture (the true criterion of transverse strength) for the same breaking load on the five diameters will be evident.

It is hoped that the expression of transverse breaking loads as rupture moduli will become general. The tensile test is expressed as a specific stress, and the transverse test should be treated in the same way. It would bring English practice into line with Continental, where all transverse results are expressed as rupture moduli. Furthermore, although the bar diameter or dimensions must be carefully measured in order to work out a rupture modulus for a breaking load, it is not necessary to specify the exact dimensions in published results; the nominal cast size, however, should be stated.

It is sometimes objected that expression of transverse loads as rupture moduli would lead engineers to suppose that the same modulus can be got from a large as from a small section on account of the assumption that rupture modulus is independent of the section. This, however, is equally true of the tensile test, and yet it is well understood that a large section will not yield the same specific stress as a small section.

The arithmetical difficulty is a somewhat serious one. In the case of round bars, assuming that they are round and not oval, graphs can readily be worked out by means of which breaking loads can be converted to rupture moduli for any diameter, similar to Fig. 1.

The Shear Test.

Various attempts have been made from time to time to examine the shear test as a means of routine testing of cast iron. In so far as it is a combination stress capable of being resolved into simple tensile and compressive stresses, it is neither better nor worse than the transverse test, which, however, gives the added useful indication of the deflection. The shear test has the following disadvantages:—(1) Of needing machining, and in the case of this test, machining of a very accurate order; (2) of needing a tensile testing or equally expensive machine; and (3) of liability to bending stresses during the test.

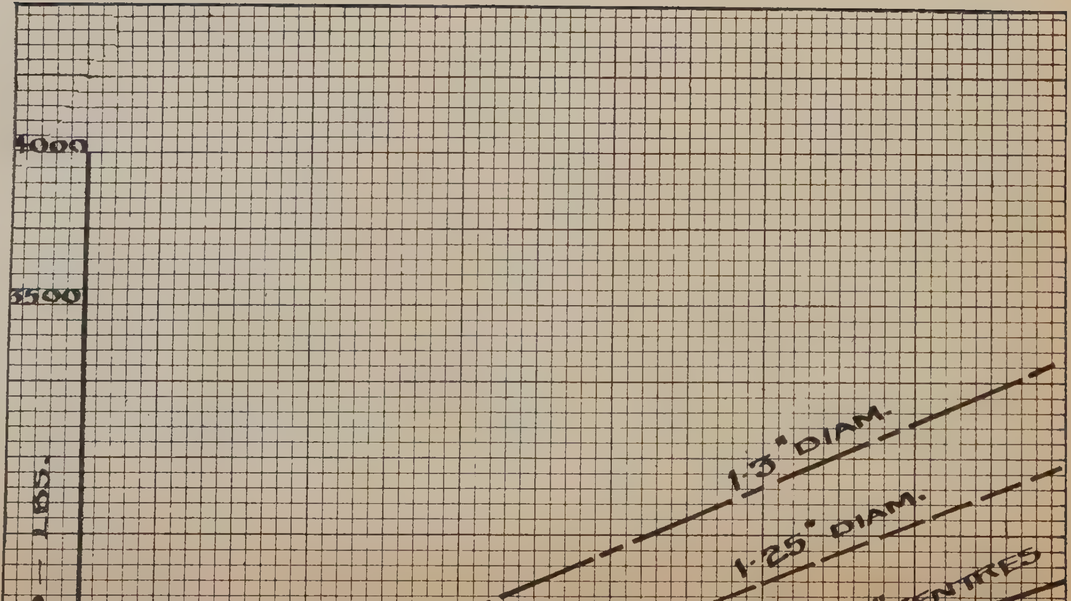
Shear testing of a practical character can be carried out in one of two ways. It is possible to shear a cast plate in a suitable shearing device, or a rod may be sheared by suitable shackles.

The rod test has the merit of being easier to prepare. Tests have been made in the shackle form on a cylindrical test piece $\frac{3}{8}$ in., $\frac{1}{2}$ in. and $\frac{5}{8}$ in. diameter. Tests are made in single or double shear according to whether the specimen is broken in one or simultaneously in two places.

Tests have also been made on small pieces 0.22 in. diameter in a shearing device consisting of a steel box into which a steel tongue fits. In this device the test specimen is placed in holes through the box and tongue, the tongue being compressed in the machine and the specimen thereby put in a double shear. Since in both tests the rod is surrounded on all sides by three parts, the two methods are the same in principle. They merely differ in construction on account of the varying size of the bars to be tested.

The tests were done on the small bar because the shear test has recently received a good deal of attention in France, and suggestions are being made with the object of ensuring the adoption of the shear test for international testing. Frémont, deciding that it was illogical to test a separately cast bar, and that the tensile test was inadequate for cast iron, devised a single shear testing machine. Single shear is an effect similar to that of an ordinary pair of scissors. This test is made on small bars 0.22 in. diameter, which are actually trepanned by means of a hollow drill from the casting itself, the total diameter of the hole being about $\frac{1}{2}$ in., subsequently plugged.

The French proposals have been examined both in this country and in America, but have so far not met with acceptance. The objection to testing the casting itself has been dealt with above, and the suggestion to test a bar of such small diameter taken from a heavy part of the casting can only be viewed with apprehension. The casting here will be at its weakest, and the size of the test piece is so small that any representative figure is impossible. The objection to the Frémont test is not an objection to the shear test itself, which has been shown to be quite suitable for cast iron, but inconvenient and expensive compared with other tests which are available. The objection to the Frémont test lies mainly in the fact that it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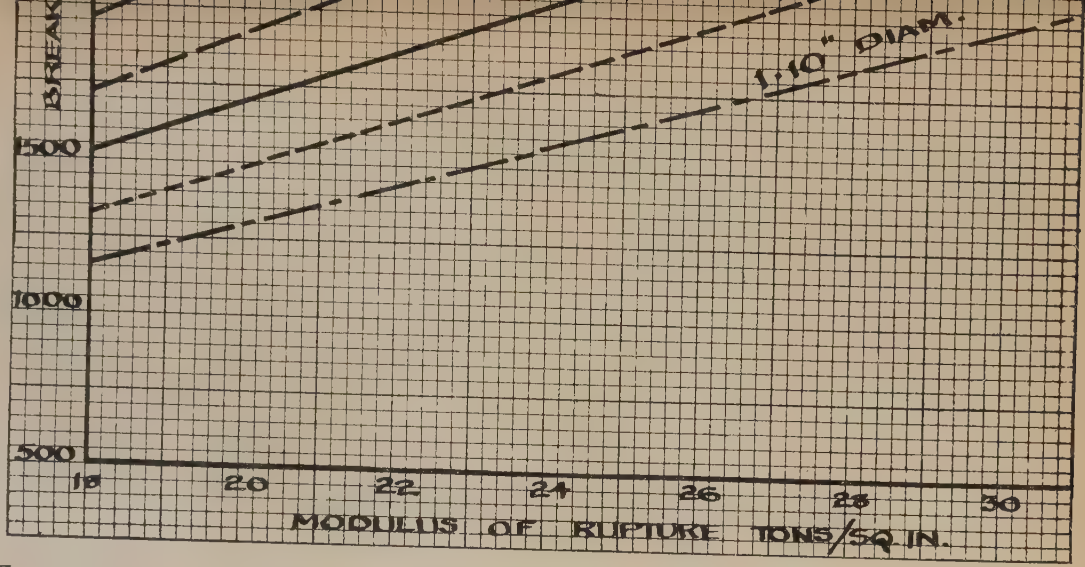

FIG. 1.—GRAPH FOR CONVERSION OF BREAKING LOADS INTO RUPTURE MODULI FOR ROUND BARS OF 1.1 TO 1.3 IN. DIA.

attempts to test the casting by such a small size of bar.

The method has been criticised both in this country and America for other reasons. The testing machine used in France for this purpose does not appear to be very robust, although it has the saving merit of being comparatively cheap. The lack of robustness, however, arouses criticism among engineers, who also do not like tests made in single shear owing to liability to other stresses. The smallness of the test piece results in any error being magnified many times in working out the specific stress. Another serious objection is that the drill does not leave the test piece with sufficiently good finish for a shear test, which should be machined as fine as possible. The drill leaves a comparatively coarse finish. It is suggested that on a single small piece several shear tests can be made and averaged, from the skin of the casting inwards, but such an average is meaningless when applied to castings of different thicknesses, or even from different thicknesses of the same casting. The test appears to be extremely ingenious, and for research purposes, for exploring the strength of the metal in different sections, appears to have advantages, but for routine testing it cannot be recommended.

In order to examine the suitability of the shear test as a routine test for cast iron, a suitable and very uniform piece of iron was cut up. It was originally a piece of a liner 1½ in. thick of very good composition, tensile strength being 17.2 tons per sq. in. (0.564 in. diameter) and transverse rupture modulus 33.2 tons per sq. in. on a 1 in. sq. bar. Shear tests were made on round bars 0.625 in. diameter and 0.375 in. diameter in shackles capable of putting the specimen in double shear when pulled in the tensile machine. Bars of the recommended French diameter, 0.22 in., were also tested, but in the steel box referred to above. Tests in this case were made by registering the test piece through a hole in tongue and box, such that movement of the tongue put the specimen in double shear. The specimen was also double-sheared by the *edge* of the tongue, the contact with the specimen being line contact only.

Finally, by allowing the specimen to project through one side of the box only, it was put in single shear by the tongue. The results show that the shear test obtained depends to a large extent on the method of testing. The results are the mean of four readings in each case and in each case the four readings were concordant, although differences between tests are marked.

Ultimate tensile strength (0.564 in.)	17.2	tons per sq. in.
Transverse strength (rupture modulus on 1 in. sq. bar)	33.2	,, ,,
Shear strength (0.625 in. bar, double shear)	21.66	,, ,,
Shear strength (0.375 in. bar, double shear)	21.73	,, ,,
Shear strength (0.22 in. bar, double shear)	21.37	,, ,,
Shear strength (0.22 in. bar, double shear, line contact)	17.85	,, ,,
Shear strength (0.22 in. bar, single shear)	19.35	,, ,,
Shear strength (0.22 in. bar, single shear, line contact)	16.16	,, ,,

A shear test thus does not measure an absolute value, but one which depends upon the conditions of the test. The most accurate test is probably made as a torsion test on a hollow cylinder. To see whether a regular relationship existed between the tensile tests and the shear test a variety of bars tested in tensile at 0.798 in. diameter were also tested in double shear at 0.5 in. diameter. The tensile : shear ratio varied between 0.52 and 0.93. The constancy of this ratio is an important point in the French proposals for supplanting the tensile test by the shear test.

It may be added here that any test for cast iron which involves a small test piece is seriously limited in its scope. It has been mentioned above that it is not satisfactory to cast small test pieces, yet many tests on cast iron are made on such test pieces machined from larger bars. Ideally, for cast-iron testing a range of testing machines should be available, whether it be for tensile, transverse, impact or shear, so that test bars related to the cast sizes can be tested with a minimum of machining. At present the test bar is adapted to the machine, whereas the machine should be adapted to the test bar. The same criticism of smallness applies to the Frémont transverse test enthusiastically advocated in France, which is 0.315 in. × 0.4 in. × 1.4 in., tested on 1.2 in. centres. The piece is so small that a considerable amount of error may arise in reading both deflection and load, and even in France a desire has been expressed for a more satisfactory measurement of deflection.*

The Brinell Test.

The Brinell test is simply applied and is now a widely used method of testing for steel and non-ferrous metals, but it has been very generally distrusted for cast iron. The reason is that Brinell hardness has repeatedly been shown to be no measure of machining hardness of cast iron or the abrasive hardness—two most important conditions in practice. Secondly, the results are meaningless unless the position of the impression is clearly defined. Obviously a soft and ferritic centre will give a lower Brinell hardness than a harder skin. There is a rough connection between the Brinell hardness and combined carbon in ordinary cast irons, but the value appears to be affected by the size and distribution of the graphite and of the phosphide eutectic.

The Brinell test is so obviously simple and convenient and can be used on the casting itself without destroying it, that it would be of the greatest possible service if cast iron were uniform. For general use it may be added that ferrite has a Brinell hardness of about 100 and pearlite of about 200, although cast iron can be machined up to 300, or even 350. Brinell hardness over a number of impressions even on the most uniform iron cannot be expected to agree to more than plus or minus 5 per cent. on the mean value.

Relations Between Tests.

In recent years a number of efforts have been made to determine what relations exist, if any, between various tests. It would simplify our testing enormously, for instance, if there were an invariable relation between the tensile and transverse tests. Furthermore, relations between Brinell and other tests would be of enormous value because the Brinell is a simple and cheap test, and its measurement would suffice instead of tensile and transverse tests. Considerations of the structure of cast iron lead one to surmise that relationships of general application are unlikely. They have been obtained in a number of cases by an investigator, taking two or three types of test on a series of irons, say, of varying silicon content, but with all other variables constant. The results have been plotted and the inequalities in the graphs smoothed out and the equation to the line obtained. Their partial truth, for one set of conditions only (*i.e.*, composition, test bars, melting conditions, moulding conditions), is evidenced by the variety of lines from various sources, and about 30 relations between one test and another have been published, chiefly on the Continent. Their variety is sufficient to show that no single one can be true.

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* Bulletin de L' A.T.F., p. 425, 1927.

There is an irregular relationship which we generally take to be 4 to 1 for compression to tensile, and 1.8 or 2 to 1 for transverse to tensile.

The advantages of standard tests on a standard bar becomes apparent on accumulating routine results. Thus in a German foundry it was found on examining 2,000 test results on 1.2-in. and 0.8-in. bars with silicon, between 1.2 per cent. and 3.2 per cent. and other elements practically constant, that with a total carbon and silicon of 4.8 per cent. the strengths of both bars are practically identical, and the lines separate as the ferrite increases. In America it has been found that any iron having an ultimate tensile strength of 18 tons per sq. in. in a 1.2-in. bar are defined by T.C. 2.5 to 3.15 and Si. 1 to 1.8 per cent.

DISCUSSION.

The CHAIRMAN (Mr. Ambrose Firth) said they had listened with very great interest to the Paper, and there was no doubt that the specification which the Association had been able to get accepted would be of very great value to ironfounders generally.

MR. GOODWIN (President of the Institute) said that Mr. Pearce was to be congratulated on the lucid manner in which he had dealt with this far-reaching work that had been so successfully launched out by the Test Bar Committee, on which both the Institute and the British Cast Iron Research Association were strongly represented. Being connected with both the Institute and the Association, he, Mr. Goodwin, had personal knowledge of the enormous amount of work that had to be done before this specification could be issued. They had wisely worked in conjunction with various important engineers in this country in order that their acceptance of this specification, when finally presented, would be a foregone conclusion. Both the metallurgist and the engineer had been seeking knowledge for a considerable number of years on the subject of test-bars, and it was gratifying to find that the results of the work done had brought about a general agreement.

Not the Last Word.

He believed that no manufacturer should have any difficulty in meeting the specification in question if he took advantage of the facilities offered for obtaining practical and technical knowledge, and the exchange of ideas at the lectures of the Institution. There were, however, many things Mr. Pearce had said which led one to believe that this was not the final specification. There were many difficulties to face in the future, when the specification for still higher grades of cast iron was drawn up, and before this could be done, one realised that a large amount of investigational work would be necessary. He asked if it had been attempted in the research which had been carried out in the laboratories to machine two test-bars, one from the top edge and one from the bottom edge, of an ordinary 2 × 1 tensile cast on edge, and if so, what were the results? From his experience, he found that there was a considerable difference in the two tests.

The French had attempted to give the engineer a test-bar cut from the casting, but unfortunately, in his opinion, the method of doing so was less likely to represent the casting, than would a separately cast test-bar of the same metal, especially as it is now possible to choose a test-bar the area of which will cool at the cooling rate of the casting to be made.

The method of machining the French test-bar, caused it to set up naturally small cracks which had an adverse effect on the ultimate breaking load of the bar, and unless those responsible were prepared to enlarge the diameter and grind the specimen in the same way as is done with British bars after machining, good results would not be obtained. He looked forward to the International Conference report from Mr. Pearce on the whole of the test-bar question.

Commander Jackson said that they were fortunate in having both the lecturer and Mr. Goodwin, the President of the Institute, who was also a member of the Test-Bar Committee, present, to tell more about this important subject. He asked if any of the test pieces had been cast round in section, and then prepared and tested.

He also asked if the Admiralty, War Office, Lloyds and other bodies would substitute the proposed specification for their existing specifications? He also said that a tolerance of one-tenth of an inch seemed to be rather excessive.

Mr. E. J. Brown said that he understood Mr. Pearce to say that the different results obtained on testing a round bar as cast, compared with a round bar that had been machined from the square, was a testing effect and not a casting effect. This was not quite clear. On casting a square-sectioned bar, cooling, of course, would proceed from each face and would result in diagonal lines of weakness. These lines would surely affect the result of the test; it therefore seemed reasonable to suggest that the difference obtained was due to casting and not to testing.

With regard to the question of whether or not the test bars should be part of the casting, he was inclined to the view, all things considered, that, provided discrimination was used, it was better for the bar to be on the casting.

Mr. Pearce had recommended that the result of transverse tests should be expressed as modulus of rupture. If the sectional shape of a bar can influence the breaking load seriously, when the figure is expressed as weight per area section, such a fact would tend to discount the calculated values obtained.

Mr. Pearce, in reply to the points raised by Mr. Goodwin, said that if transverse test bars were machined from the top and bottom edges of a 2-in. by 1-in. transverse bar, the results would be very different. It was well known that the result from the 2-in. by 1-in. bar varied according to the way in which the bar was poured and tested. Tests of the kind mentioned had been made, to his knowledge, from broken 2-in. by 1-in. bars, which were machined to 1-in. square and tested at 12-in. centres. There was usually on the 1-in. bars a relative increase in stiffness—that is, in breaking load—and a decrease in deflection, and there was a difference between the bar from the top and the bar from the bottom. So far as he knew no tests had been made after the manner of the Frémont test on over-size bars ground or machined to size.

In reply to Commander Jackson, he said that all the important authorities mentioned have been represented on the B.E.S.A. Committee and would doubtless use the specification in place of individual specifications hitherto used. He agreed that the tolerance was on the high side, but it was better not to make a specification too stringent to start with, but to improve it later as founders got accustomed to using it.

In reply to Mr. Brown, he said that part of the difference between the round bar and square bar was undoubtedly a casting effect. The test referred to in the paper showed that what had hitherto been supposed to be wholly a casting effect was, in part, a testing effect, because the round bar gave better results than the square bar, irrespective of the shape of the bar from which either had been machined. No doubt, as a result of a good deal of experience, it was possible to arrange a cast-on bar fairly to represent a casting, but this cannot be said of all cases.

In calculating rupture modulus the shape of the bar was taken into account in the formula by means of the factor Z, or section modulus.

At the close of the meeting Mr. Pearce was accorded a very hearty vote of thanks for his highly interesting paper.

Scottish Branch.

SCOTTISH MOULDING SAND.

By F. Hudson (Member).

The object of this Paper is to accentuate the need for learning more about foundry sands. In Germany and in America one is impressed with the formation of committees to explore and apply this material to the best advantage. In this country foundrymen appear to be a little backward in this respect, but there is little question that in future foundry work the control of moulding sands will be a very important duty to those who wish to keep an eye on profits.

Science, hand in hand with labour, is inscribed upon the seal of the Institute, and it is felt that in those words lies success to any study or investigation upon this question. This inscription, in fact, has been running through the minds of the metallurgical staff of Glenfield & Kennedy ever since this investigation was started in February last year, and although it has obtained something for its labours, yet it has still a long way to go. However, it stated quite clearly that this is not a scientific Paper, but a Paper as practical as it can be, and it is hoped that it will be of some value to founders in general. The best promise for the success of the industry seems to lie in the co-operation of each one of its members with the other, and the author makes a plea at this time for as many members as possible to take up sand testing and study the results they obtain, as well as giving it away for the help of others. The apparatus needed is quite inexpensive.

The Ideal Sand.

Before describing the apparatus used, and the results obtained in the tests on the various supplies of Scotch moulding sands, it may be as well to define an opinion as to *the ideal moulding sand*, in order to gauge the relative merits of each. In this connection the author firmly believes that one sand will never give satisfaction to the foundry trade as a whole, and therefore *the* ideal moulding sand will only exist in the singular for one typical application. Ideal sands must be developed for non-ferrous work, others for cast iron, and still others for steel castings. To get the best results the sands used in these three particular branches of foundry work must be still further sub-divided, according as to whether castings are made in green sand, dry sand, or loam, or whether the sand is used for moulding ornamental stove-plate work or heavy structural parts. In one instance the most looked-for property of an ideal sand is its power for producing a casting with a smooth skin, whilst venting properties rank second in importance. On the other hand, many require a sand having excellent venting properties, but with skin-producing power in the second place.

These remarks clearly suggest that each one will have quite a different conception of those properties which go to make the ideal moulding sand, according to the kind of work produced. However, in the physical properties of the various sands examined, as will be shown later, provision has been made for selecting the sand most suitable to a particular application providing a practical interpretation can be applied to those properties required of the sand for successful casting production. Taking the author's own requirements for grey iron hydraulic engineering castings as a concrete example, an ideal would consist of a sand having excellent bond yet as open as possible consistent with fairly good skin production. In this instance, a sand composed of medium uniform one-grade silica or quartz grains of a spherical or slightly sub-angular form, with each grain coated with the minimum amount of strong bond to give the necessary cohesion, would be required. The efficiency of the sand would greatly depend on the strength of the bond, as the stronger the bond the less would be required to cement the grains together, and the sand would be correspondingly more open. Such an ideal is exemplified in Fig. 1. The top diagram represents the theoretical way an ideal moulding sand should pack under the rammer. The white circles represent the one-sized quartz grains. Around each grain is the bond represented by the "inlined" portion. The black spaces between the grains determine the porosity of the sand. If such a sand could be obtained it would be impossible to ram too hard, but at the same time if it contained excess bond this would be squeezed away from the grains and would block up the pore spaces, and so cause impermeability. This diagram can be said to represent an ideal sand suitable for general grey iron work.

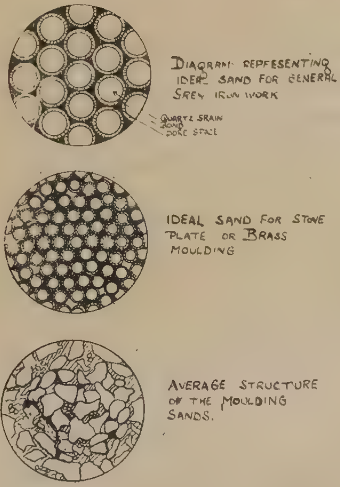
DIAGRAM REPRESENTING IDEAL SAND FOR GENERAL GREY IRON WORK
QUARTZ GRAIN
BOND
PORE SPACE
IDEAL SAND FOR STOVE PLATE OR BRASS MOULDING
AVERAGE STRUCTURE OF THE MOULDING SANDS.

FIG. 1.—IDEAL MOULDING SANDS DIAGRAMMATICALLY EXPRESSED.

In the middle diagram a similar state of affairs exists, except that the quartz grains are smaller, and although the total area of pore space is the same as in the diagram above, yet such a sand will have less permeability and would be more adapted to brass-foundry work.

In the bottom diagram there is represented the state of affairs which exists in ramming a moulding sand made up of varying-sized grains and carrying excess bond. What pore spaces that are available are completely blocked by the excess bond at the expense of permeability. Unfortunately, it is only too true that this latter example is most typical of the sand used by most foundrymen. It should be clearly understood that there is a large difference between the porosity of a moulding sand and its permeability. Porosity can be stated as the total area of pore spaces over a certain section, whilst permeability is the resistance offered to the passage of gases through the pore spaces.

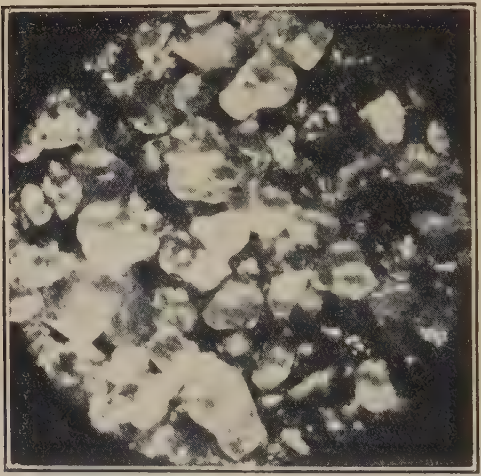

FIG. 2.—DRIED CORE, MADE FROM AN OIL-SAND MIXTURE × 40.

Fig. 2 is a microphotograph taken at 40 magnifications from a dried core made in sea sand bonded with linseed oil. At the present time this is the nearest practical approach to the expected structure of an ideal moulding sand. It should be noticed that the quartz grains are uniform and nearly all of one size, whilst the sand is open and quite permeable. The bond in this instance is covering the grains so finely as to be not noticeable, yet excellent strength was obtained. Fig. 3 shows the structure of ordinary clay or loam, and although the magnification is exactly the same as in Fig. 2, any sand grain present is entirely obliterated by excess bond. As a result, this material is absolutely impermeable, although admittedly quite strong. It may be of interest, however, to learn that even in the matter of strength, the sea sand, bonded with the oil, was superior to the clay, when both these sands were tested in the dried condition.

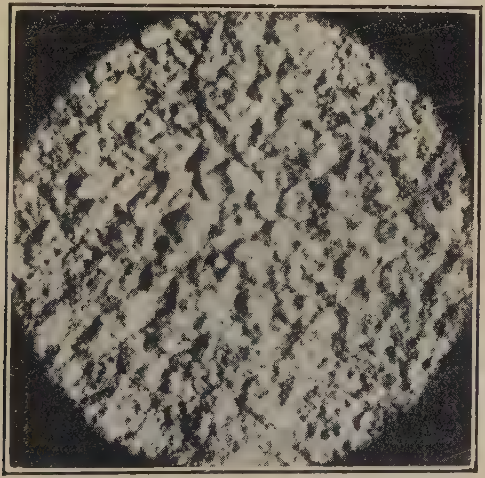

FIG. 3.—ORDINARY LOAM × 40.

Thus the size and quantity of the quartz sand grains which go to form a moulding sand, together with the quantity and distribution of the bond are of great importance in selecting an ideal sand for use in foundries. As a guide to decide what would constitute an ideal sand for different purposes, Smalley gives an excellent little table in his paper* on moulding sands, and reproduced in Table I, which shows quite clearly in a general way the order of merit of the physical properties required by sands for the casting of various alloys.

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* Proceedings of the Institute, Vol. XVI, 1922-23, page 321.

Taking the column for cast iron as an example, one notices that the most important first quality of a moulding sand for general purposes is that of bond, followed by permeability. For light ornamental cast-iron work one would think that the column under the bronze heading would be acceptable as an ideal, as in this instance texture, or skin-producing powers, come first, followed by bond in the second position. Altogether this table can prove an excellent help, provided it is accepted in a general manner.

Table I.—*Requirements of Moulding Sand for Various Alloys.*

Aluminium and its alloys.	Brass.	Bronze.	Cast iron.	Steel.
Bond	Bond	Texture	Bond	Refractoriness.
Texture	Texture	Bond	Permeability	Water content
Water content	Refractoriness	Heat conductivity	Refractoriness	Heat conductivity
Permeability	Longevity	Longevity	Texture	Bond
Heat conductivity	Water content	Permeability	Longevity	Permeability
Longevity	Permeability	Refractoriness	Heat conductivity	Texture
Refractoriness	Heat conductivity	Water content	Water content	Longevity

Methods Used in Testing.

The policy followed after much consideration and experimental work has been to instal apparatus for laboratory work and other instruments for practical testing of the sand and actual moulds. At the present time nearly all of the apparatus used by various investigators has failed to give any results whatsoever when applied to actual moulds in the foundry. If research work is done in the laboratory, the practical results cannot be successfully concluded unless one knows exactly what is happening to the sand during the initial preparation and consequent mould manufacture.

As a simple example, an excellent sand found most satisfactory under laboratory tests may turn out hopeless castings, due to more water or harder ramming in the foundry compared with that applied in the laboratory. The use of practical routine control instruments is quite an obvious need to supplement laboratory work, and for the general information of the foreman. Although experimenters have only recently devised instruments for this latter work, yet they are included in this paper to give an idea of future intentions

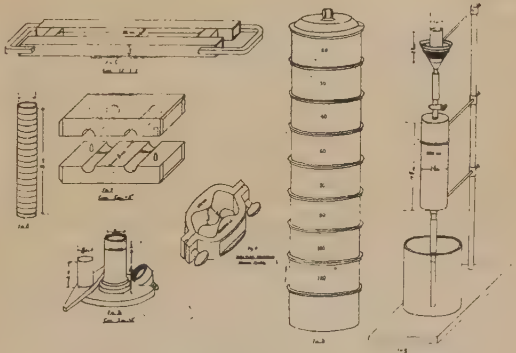

Fig. 4.—Laboratory Sand Testing Apparatus.

in attempting to obtain control over practical sand and moulding operations. However, except for their description and use, it is not intended to dwell long on this subject, as it lies outside the scope of this paper.

The laboratory apparatus used was that employed by Smalley, as described in his aforementioned paper. This apparatus was selected for two reasons, the first being the fact that his paper includes a series of test results showing the properties of English moulding sands, and a comparison of Scotch sands would prove of interest and value. The second reason was, that the author worked under the direction of Smalley in preparing sand tests with this apparatus, and was quite conversant with it before preparing this present work.

Fig. 4 gives a perspective dimensioned sketch of the laboratory testing apparatus. A is an ordinary glass tube graduated in inches for doing Fletcher's excellent and informative subsidence test; B is a set of sieves for mechanical grading; C is a core box for obtaining the green-dropping test used to determine the relative bond in green sand. (This box is also used to obtain the transverse test for dry sand work); D is the apparatus used for ramming the green sand permeability test; E is the mould for dry sand tensile test; F is the core box for the dry sand permeability test, and G the aspirator used for drawing air through the different permeability tests and showing in this case a dry sand core in position at the top.

Texture.

For this purpose the sands were put through 120, 100, 90, 80, 60, 40, 30 and 20 mesh sieves, the amount passing each being recorded as a percentage of the total under a heading of mechanical grading. These simple sieve tests give a great deal of information regarding the grain size of the sand and the proportion of clay and silt grades present. At the same time there are many technical objections to this method, two of the more important being the shape of the sieve mesh and the fact that certain sands carry a thick coating of clay around the sand grains, which naturally makes the true grain of the sand larger than it really is, and records less clay present. It would seem that to obtain an accurate result, instead of treating a dried sample, one must treat the sand in boiling water, as even repeated washing with cold water in some sands does not clean the bond from the grains.

In Table II is reproduced the results of a German investigation on this question. The large difference between the clay contents of sand treated ten times with cold water and the same sample treated with boiling water is worthy of note. In the present tests all grading was done on 100 grms. dry sample. In confirmation of these results Fletcher's subsidence test was applied. The method of doing this test has been fully described.* Its basic features depend on shaking a certain volume of dry sand up with water in a graduated glass tube and timing the fall of sand. It can readily be understood that a fine sand will fall much slower in water than a coarse sand, and that clay due to its colloidal nature will be held in suspension until the sand grains have settled. After the results are plotted on a graph one obtains a very valuable guide to the texture of the sand, the relative amount of bond present, and a sure means for applying a quick test in finding out the location of a questionable sand. Fig. 5 illustrates the glass tube and appearance of the sand column after completion of the test, showing the coarsest sand grains at the bottom and the clay deposit on the top. In the author's

TABLE II.—*Comparison of Sample Treated with Cold and Boiling Water.*

	Treated 10 times with cold water.		Treated with boiling water.	
		Per cent.		Per cent.
Size of meshes measured microscopically in m.m.	Sand Content	92.0	Sand Content	84.3
	Clay Content	8.0	Clay Content	15.7
0.5		5.4		2.6
0.3		2.2		1.3
0.2		28.4		16.4
0.15		42.7		45.9
0.12		5.2		7.5
0.08		4.3		5.9
0.06		0.6		0.8
0.05		1.1		1.5
Smaller than		1.4		1.8
0.05		0.7		0.6
Weighing loss		92.0		84.3

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* "Foundry Trade Journal," Nov. 4, 1926, p. 389.

experiments it has been the practice to perform these two tests first in examining any sand.

The sand sample is now divided into two portions to determine its suitability for green sand and dry-sand work. The sand is tempered to give 7 per cent. moisture, for green-sand work, and 1 per cent. moisture for dry-sand work. In tempering the sand the practice is to determine the existing moisture content and then adjust the sand either by air drying or by adding water to give the required figure. It is not good practice to drive off the moisture in the sand by heat and then add the required amount of moisture unless the sand is allowed to stand for at least 10 hours, as it was found that the correct properties of the sand did not develop under this time.

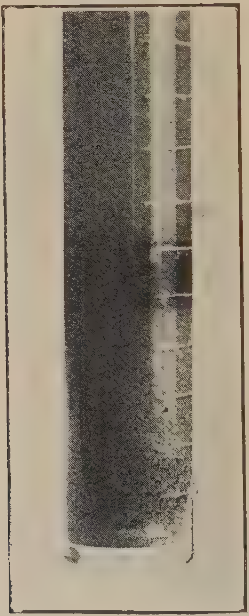

FIG. 5.—FLETCHER'S SUBSIDENCE TEST.

Green Sand Testing.

Two tests are made to determine the suitability of a sand for this class of work, the first being called the green dropping-test, which gives an excellent index of the strength of bond. The sand is rammed up in a skeleton core box on a $\frac{3}{8}$ in. thick glass plate to give a bar of sand 12 in. by 1 in. by 1 in. long. The glass plate projects over the edge of a bench, and the sand is gently pushed over the edge of the plate until the sand collapses. The length remaining (measured from the middle) substracted from the original length, is recorded as a measure of the bond, the average of at least four tests being taken. The second test is to determine the permeability of the sand. In this case a green-sand core 3 in. long by 1 in. diameter is rammed up in the apparatus, as shown in Fig. 6. Figs. 7, 8 and 9 indicate progressive stages in obtaining the core free from ramming variations. Fig. 10 shows the core in place on the aspirator ready for testing when the cock at the top is opened and the water in the cylindrical container escapes and sucks air through the core. The time taken for the water to fall from the extreme top of the aspirator to a fixed mark on the glass outlet tube is an index of the permeability.*

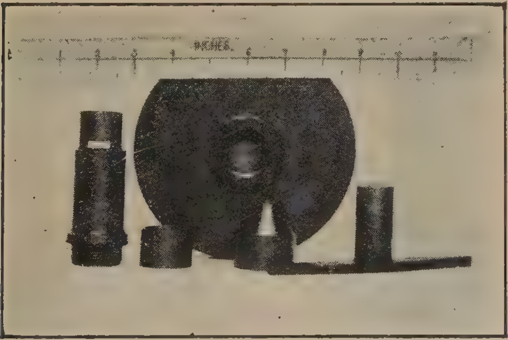

Fig. 6.—Apparatus for Green Dropping Test.

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* For further description see Smalley's Paper, *loc. cit.*

Dry Sand and Loam Testing.

To obtain the strength of dry sand and loam two tests are made. A tensile test is rammed up in a British Standard cement mould, and a transverse test made on a bar of sand 6 in. long by 1 in. by 1 in. This latter test piece being made in the skeleton core box as used for the green dropping-test. These are now dried for about 4 hours at 450 deg. Fah. in an electric oven. Fig. 11 shows the oven with sample test-pieces in the front. After drying and cooling to room temperature these test pieces are broken as shown in Figs. 12 and 13. The tensile bar is placed in steel grips, and a bucket suspended, to which weights are added. In this case the bucket was omitted and a different kind of load applied

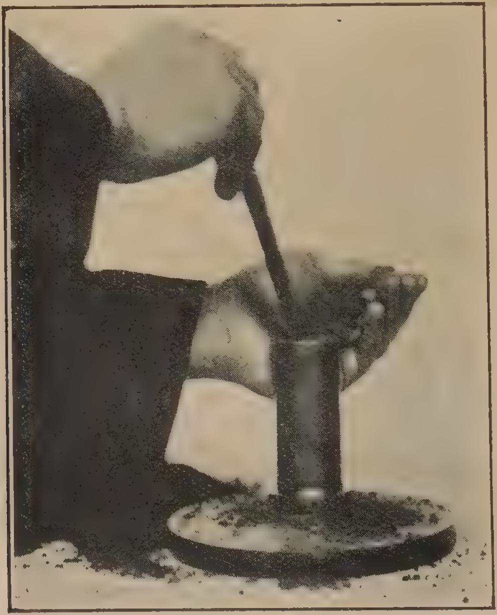


FIG. 7.—RAMMING THE SAND IN TUBE.

which indicates the excellent strength shown by some moulding compositions. The test piece in question was made from sea sands plus

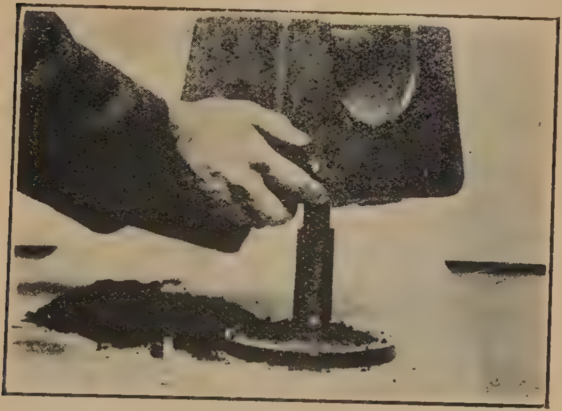


Fig. 8.—Applying Standard Pressure.

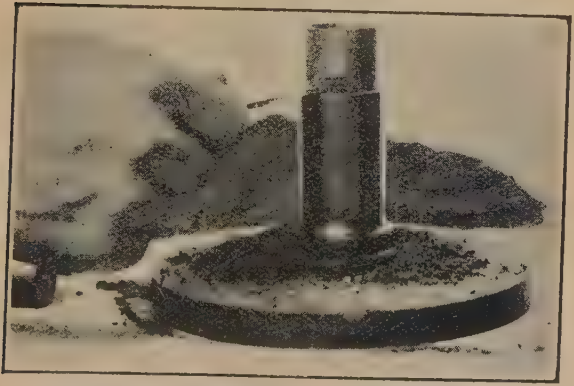


Fig. 9.—Gauging the Volume to be Used.

2½ per cent. of linseed oil, and was 1 in. square at the breaking face. Fig. 13 shows a transverse test piece under load. In this case the test piece is supported from 4-in. centres, and the load applied centrally, through a ¼ in. diameter bar. The breaking load in either case is obtained in ozs. per sq. inch.

The permeability test for dry-sand work is rammed up in a split core box to give a 3 in. long by 1 in. dia. column of sand This is dried exactly the same as the previous test pieces, and when cold is mounted in a glass funnel with wax. Fig. 14 shows the core box and mounted test piece under test in the aspirator, and Fig. 15 gives a close-up view of the mounted test piece. The method of mounting is as follows:—When the test piece is cool ¼ in. of the length is cut away, and holding the test piece by the end it is immersed in paraffin wax. Two immersions are required. (It is important to have the wax at the correct temperature, for if the wax is too hot then it will penetrate the test piece. On the other hand, if the wax is too cold, air leakage will take place.) The dipped test-piece is now

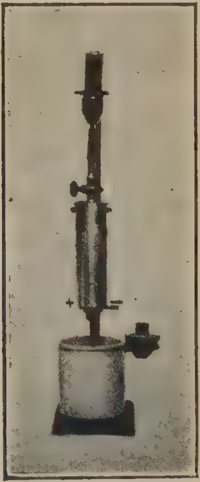


FIG. 10.—TEST CORE IN PLACE IN THE ASPIRATOR.

placed in the funnel, and plasticine pressed into position at the base to prevent the wax leaking into the funnel stem. Molten wax is now poured into the funnel around the test piece. When firmly set at the top the test piece is cut open as shown.

In conjunction with these tests, wherever possible, a further test is applied to give an index of the skin producing and refractory powers of the sands. In this case a mould was made in the foundry, as outlined in Fig. 16, when all the sands examined could be made up into 2 in. wide blocks to form the base. These blocks are made from individual virgin sands in the dried condition, each being rammed as hard as possible with the same moisture content. Two ladles of hot iron are now poured into the mould to produce a block 34 in. long by 5 in. wide by 2½ in. thick.

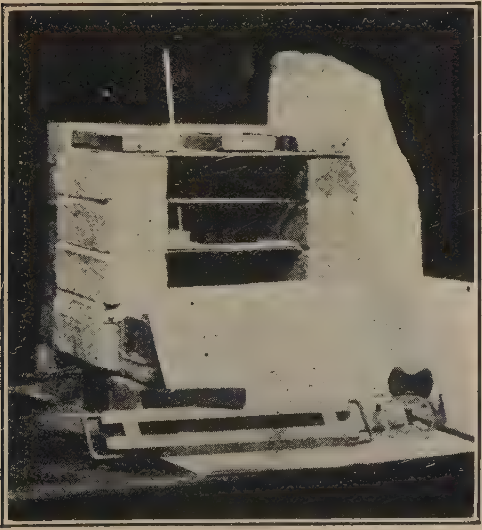


FIG. 11 SHOWS THE OVEN, WITH SAMPLE TEST PIECES AT ITS FRONT.

When cold, if the block be extracted carefully, the refractoriness of the various sands can be gauged according to the amount of sand fritting which has taken place, and the skin-producing powers readily shown after sand blasting.

Some Common Scotch Moulding Sands.

The tests just described were applied to twenty-one different Scotch sands, five of them being red sands, thirteen of the rotten-rock group, and three silica sands. Fig. 17 gives the results of Fletcher's subsidence test on these sands. The continuous lines on this graph are silica sands, the crossed lines red sands, and the dotted lines the rotten-rock class of naturally-bonded moulding sands. It will be noticed that on the extreme left

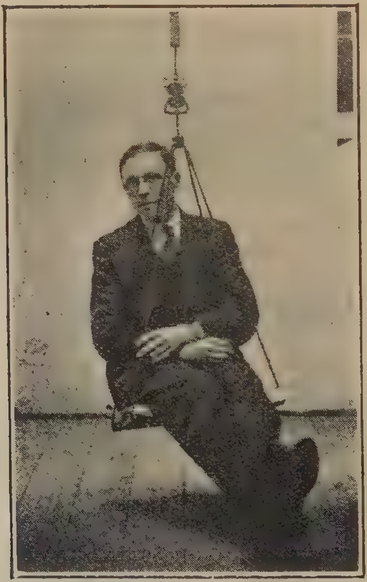


FIG. 12.—TENSILE TESTING APPARATUS. THE TEST PIECE IS AN OIL-SAND MIXTURE, AND IS ONLY 1-IN. SQUARE AT THE BREAKING FACE.

there is a straight line representing Irvine sea sand, whilst at the extreme right a curve representing common clay. The straight-line graph denotes a fairly uniform-graded sand, free from the clay and silt grades. This sand subsided in the test tube at an equal rate according to intervals of time. On the other hand, the graph representing clay subsided uniformly for a few seconds and then the subsidence became gradually slower and slower, shown by the bend in the graph This bend represents the point when the sand grains have subsided and the beginning of the clay subsidence.

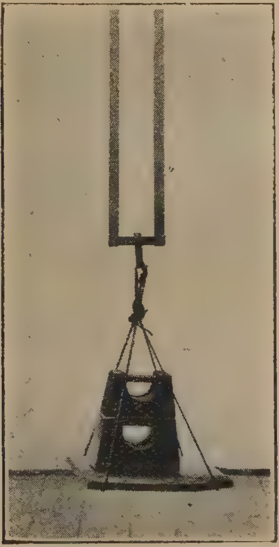


FIG. 13.—TENSILE MACHINE NORMALLY LOADED.

As 3 ins. of dry sand was used in the test tube for all the sands, it is obvious that those sands, having their graph extremities on the 3 in. line, contain a relatively small proportion of clay and silt grades. All others contain different clay

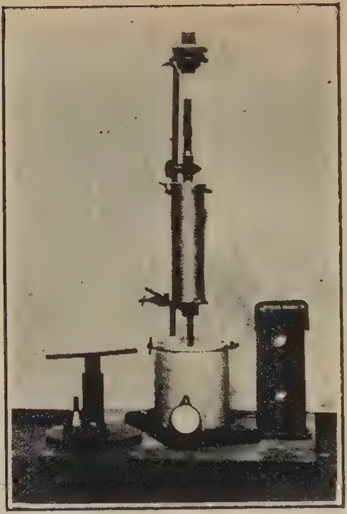


Fig. 14.—Permeability Testing Apparatus.

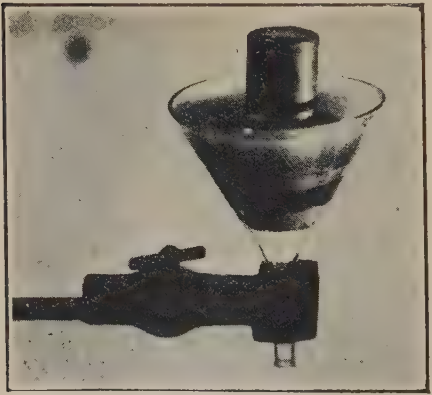


Fig. 15.—The Mounted Test Piece.

contents according to the amount of final subsidence between 1 to 3 in. For practical purposes it can be said that all sands having a straight line graph with an extremity on the 3 in. line contain no clay. Irvine sea sand and Kilwinning silica sand belong to this class. Furthermore, the lower the incline of the graph then the finer the texture of the sand. In this respect it should be noticed that Irvine sea sand is the coarsest sand examined, whilst Blairgowrie sand is the finest. Those sands having a bend in the graph near their extremity on the 3 in. line contain little or no clay, but perhaps a small amount of silt. Examples of these are typified by the sands shown between and including Caldwell silica sand and Wigtonshire red sand. Other sands between Loudoun rock (not milled) and clay contain a varying percentage of clay, the greater as they approach this latter sand. An exception to this, however, is shown by Blairgowrie sand, which contains surprisingly little clay, as is shown by its straight line curve, and its position is due to its extremely fine texture and the short period of the test. From this graph the relative texture and clay content can be seen at a glance, and it is of

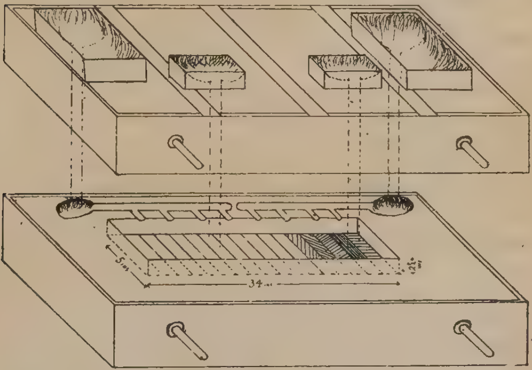


FIG. 16.—REFRACTORINESS AND SKIN PRODUCING TEST MOULD.

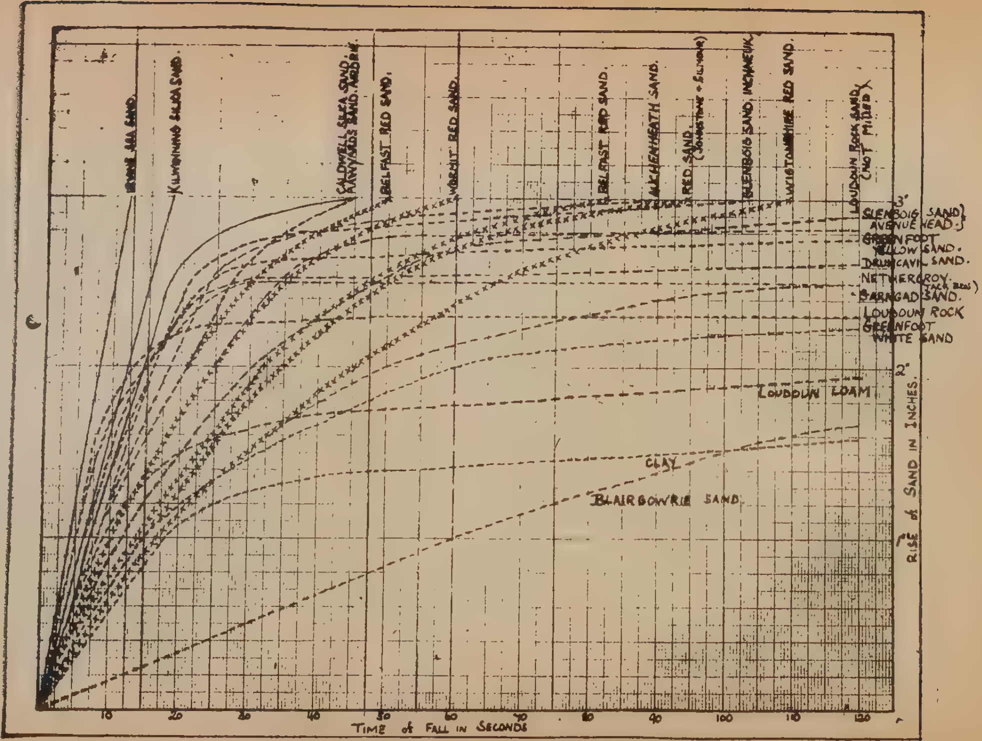


FIG. 17.—SUBSIDENCE TEST RESULTS ON SCOTTISH MOULDING SANDS.

surprising value in distinguishing between different grades of similar coloured sands, as the complete test takes only about 5 minutes. It is to be preferred over the sieve test as regards time and simplicity, and also in regard to the ease in comparison of the various sands.

Table III shows the results obtained on the sieve test, and the strength and permeabilities of the sands when used for green and dry sand work. These figures have been rechecked, and each is the average of two test-pieces. From this table it is possible to foresee the value of each sand for the various branches of moulding, and the suitability of sands for casting different alloys. It is also invaluable for making up new sand mixtures, as it is possible to obtain a far better idea of the physical properties of the mixture when the properties of the sand added to that mixture are known. It is interesting to note that the sieve tests on the red sands and silica sands check with Fletcher's subsidence test as an indication of sand texture, but the other sands containing clay are inclined to vary. This is no doubt due to the clay coating on the sand grains not being removed, as described earlier.

It is interesting to note that most sands have less strength in the green condition when the moisture content exceeds 7 per cent., and higher permeability for the same degree of mould ramming. The water content of sand used for green sand moulding is of vital importance, and should be about 7 per cent. If this is exceeded trouble is bound to arise, as a study of the results in this table will show. All sands, however, will vary considerably in this respect, as some sands can take more water than others yet give the same results. As an example, take Belfast sand, No. 3 in the table, which is considerably used in this district for brass moulding. At 7 per cent. moisture tested in the green condition a green dropping test of 2.1 in. is obtained, with a permeability of 104 seconds. At 10 per cent. moisture the green dropping test remains the same, but the permeability is increased to 117 seconds. *In this sand excess water makes very little difference.* On the other hand, looking at Carlisle sand, which is also a good brass-moulding sand the green dropping test at 7 per cent. moisture is 3.4 in. with a permeability of 208 secs., and at 10 per cent. moisture the green dropping test 2.4 in., with a permeability of 381 secs. *In this case the extra 3 per cent. of moisture has resulted in a 30 per cent. reduction in strength and an 86 per cent. increase in permeability.* Exceptions to this rule are seen in Nethercroy sand, Loudoun loam and clay. In Nethercroy a better sand is obtained at 10 per cent. moisture for green sand work than at 7 per cent. The other two cases mentioned require the extra water to wet the large amount of clay present.

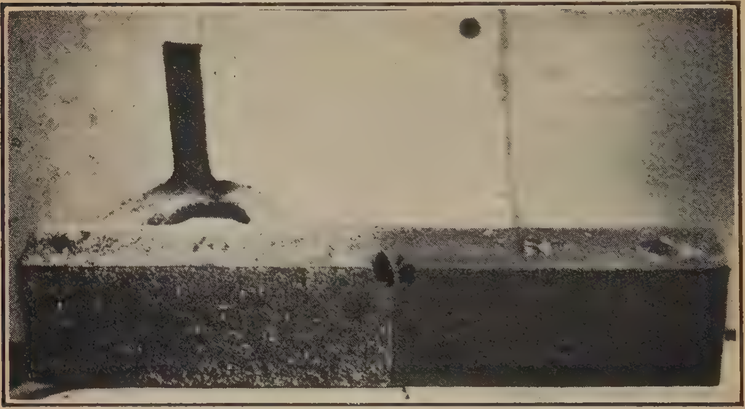
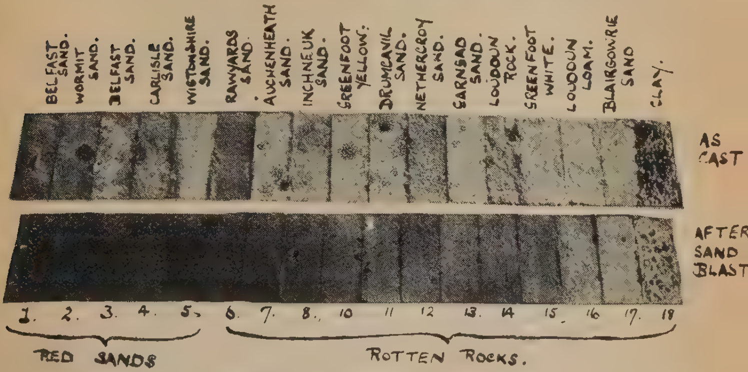


FIG. 18 SHOWS DIFFERENCE IN REFRACTORINESS AND SKIN PRODUCTION BETWEEN TWO TYPICAL SANDS.

For dry sand work it is preferable to have 10 per cent. of moisture in the sand used, as the extra moisture *increases* the strength of the sand after drying. It is also interesting to note that the transverse strength can vary from 5 ozs. per sq. inch up to 189 ozs. per sq. inch, whilst the permeability ranges from 53 secs. up to 1,142 secs., with the same amount of ramming and moisture. Surely this is an excellent reason to learn more about the sands used? In selecting the most suitable sand for dry sand moulding it is a very good rule to choose a sand which will give high strength and low permeability together. For green sand work a sand should be selected which will give over 2½ in. green dropping test and have a permeability under 60 secs. at 7 per cent. moisture. Obtaining exact practical limits for a mixture specification has, so far, not been obtained for green sand work, but with the foundry sand testing apparatus this can be obtained.



ORDER of MERIT.

(REFRACTORINESS.)
BLAIRGOWRIE SAND.
CLAY.
WIGTONSHIRE SAND.
BELFAST SAND No3.
{BELFAST SAND No 1
RAWYARDS SAND.}
SARNGAD SAND.
{WORMIT SAND.
AUCHENHEATH SAND.
INCHNEUK SAND.
GREENFOOT YELLOW.
DRUMCAVIL SAND.
NETHERCROY SAND}
GREENFOOT WHITE.
{CARLISLE SAND.
LOUDOUN LOAM.}
LOUDOUN ROCK.

(SKIN PRODUCTION.)
BLAIRGOWRIE SAND.
{BELFAST SAND No3.
WIGTONSHIRE SAND.
DRUMCAVIL SAND.
SARNGAD SAND.
LOUDOUN LOAM.
WORMIT SAND.}
{BELFAST SAND. No 1.
RAWYARDS SAND
AUCHENHEATH SAND.
GREENFOOT YELLOW.
LOUDOUN ROCK.
GREENFOOT WHITE.}
CARLISLE SAND. (SAND FRITTED)
INCHNEUK SAND (SAND CUT)
NETHERCROY SAND (OPEN SURFACE)
CLAY. (BADLY BLOWN)

Fig. 19.—Illustrates the Results from the Testing of Vari
Scottish Sands.

TABLE III.-

Name of sand.	Sieve Test.						
	Mechanical grading on dry sample (per cent.						
	Passes 20	Passes 30	Passes 40	Passes 60	Passes 80	Passes 90	Passes 100
RED SANDS.							
1. Belfast. G. Walker, Sons & Co.	99.55	99.35	99.01	95.93	84.48	78.73	76.05
2. Wormit	99.66	99.65	99.51	98.64	89.59	83.77	79.09
3. Belfast	99.39	99.30	99.09	98.18	90.75	86.28	82.57
4. Carlisle Johnstone & Gilmour ..	99.77	99.14	98.24	96.55	93.36	90.00	87.17
5. Wigtonshire. G. Walker, Sons & Co.	100.00	100.00	99.90	99.60	99.20	97.68	96.26
ROTTEN ROCKS.							
6. Ranyards sand.—Airdrie	97.65	96.24	94.35	87.78	74.50	56.13	53.23
7. Auchenheath sand ..	98.06	97.40	96.47	90.80	52.05	37.51	31.47
8. Glenboig sand. Inchneuk	95.64	92.49	86.60	70.95	28.27	21.35	18.05
9. Glenboig sand. Avenuehead	96.18	94.86	92.46	82.22	32.90	23.05	18.42
10. Greenfoot yellow ..	98.77	95.79	87.00	56.19	16.57	12.33	9.93
11. Drumcavil sand	97.51	94.20	90.85	82.85	30.19	20.62	15.10
	97.3	93.5	89.95	83.1	34.5	23.4	19.15
12. Nethercroy sand ..	93.94	75.85	53.39	26.20	10.64	9.36	6.88
13. Garngad sand	95.99	94.27	91.40	86.19	65.80	53.60	35.54
14. Loudoun Rock	90.71	89.55	88.39	80.82	63.11	52.84	46.68
	92.72	80.86	70.17	51.24	30.55	26.75	24.08
15. Greenfoot white	92.58	82.65	68.05	43.54	20.61	18.26	14.07
16. Loudoun Loam	96.64	87.59	76.84	57.90	37.53	34.16	31.28
17. Blairgowrie sand ..	100.00	100.00	100.00	100.00	99.94	99.89	99.87
18. Clay	86.21	79.15	69.89	62.09	49.06	46.78	42.47
SILICA SANDS.							
19. Irvine Sea sand ..	96.59	94.01	90.97	77.85	26.89	14.42	9.85
20. Kilwinning sand ..	98.52	97.32	94.44	73.96	23.69	15.07	13.00
21. Caldwell coarse sand ..	82.04	61.30	46.35	27.83	13.03	10.70	9.65

oulding Sands.

Rational nalysis.		Tested Green.				Dried at 450 degs. F.					
		At 7 per cent. moisture.		At 10 per cent. moisture.		At 7 per cent. moisture.			At 10 per cent. moisture.		
er t. y.	Per cent. Sand.	Dropping test.	Perm. in secs.	Dropping test.	Perm. in secs.	Tensile ozs. per sq. in.	Trans. ozs. per sq. in.	Perm. in secs.	Tensile ozs. per sq. in.	Trans ozs. per sq. in.	Perm. in secs.
		Ins.		Ins.							
.6	98.4	2.1	102	—	—	227	30	124	—	—	—
.8	98.2	2.1	107	2.08	147	153	32	161	274	45	186
.0	95.0	2.1	104	2.1	117	120	20	113	224	50	136
.2	85.8	3.4	208	2.4	381	206	50	227	596	66	414
.6	98.4	2.06	120	—	—	31	13½	148	—	—	—
.9	94.1	1.9	63	1.9	90	42	9	83	69	17	94
.3	85.7	1.8	46	1.77	63	45	12	62	74	19	91
.5	67.5	1.8	48	1.8	62	308	54	52½	420	112	220
.3	66.7	3.1	64	—	—	248	43	74	—	—	—
.7	72.3	2.3	46	1.9	48	92½	19	47	298	89	53
.7	55.3										
.6	68.4	3.2	65	2.8	102	412	55	70	730	141	90
.3	52.7	2.7	53	2.8	44	409	125	59	673	142	53
.5	62.5	2.7	130	2.3	303	195	47	149	245	77	316
3	72.7										
3	65.7	3.4	64	2.35	140	272½	49	186	478	121½	1,142
2	56.8	3.26	54½	2.8	81	236	54	53	787	189	304
6	57.4	2.0	110	4.0	197	65	6½	81	692½	168	327
1	95.9	3.0	321	2.96	416	28½	5	471	27	5	545
5	36.5	This was tested at 14per cent. moisture, as below this percentage the material was too dry to work.									
		8.8	571	—	—	2,857	992	Impermeable on Apparatus.			
1	100.00	1.2	44	—	—	—	—	—	—	—	—
3	98.7	1.2	44	—	—	—	—	—	—	—	—
6	98.4	1.0	37	(Furnace sand)							

Suitable sands for aluminium and brass moulding are typified by the finer red sands such as Belfast and Carlisle. For cast iron, with the exception of Blairgowrie sand, all the sands can be put to useful purpose, whilst those of value for steel work consist of Auchenheath, Inchneuk, Ranyards, Avenuehead, Greenfoot white, Caldwell and Kilwinning silica sands.

Fig. 18 shows the difference in refractoriness and skin production between red sand of the Bunter class and rock sand of the rotten-rock group. The red sand gives a finer skin and fettling easier when tested for grey iron castings. Fig. 19 illustrates the results obtained on all the Scottish sands tested for similar properties. In this test the sand of outstanding merit as regards refractoriness and skin production was Blairgowrie sand. The other sands are shown arranged in their order, those bracketed together having equal merit.

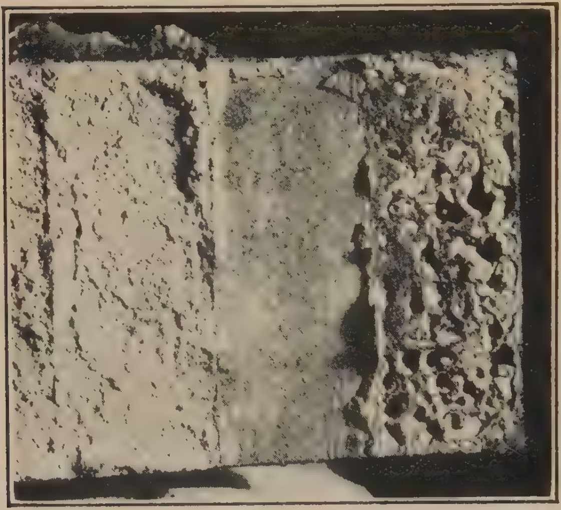


FIG. 20.– SHOWS THE RESULTS OBTAINED FROM BLAIRGOWRIE SANDS.

Fig. 20 gives some idea of the excellent refractoriness and skin-producing power of Blairgowrie sand. This is a close-up view of the block, illustrated in Fig. 19, immediately after lifting from the mould. No fettling has been done, and a perfect skin has been produced without any facing or admixture to the sand whatsoever. On one side of the skin produced by Blairgowrie sand there is the blown surface produced by the clay, and on the other the fritted and adhering burnt sand from Loudoun loam. It would seem that this property of Blairgowrie sand is due to its high mica-schist content. Unfortunately for the foundryman, this sand has rather a high-permeability and a very weak bond in the dried condition which mitigates against its successful use for general grey iron castings. If the physical properties of the sand had been normal it would be entirely practical to obtain a perfect skin on iron castings up to 2½ in. thick without using plumbago or blacking. However, the knowledge of the skin-producing properties of various sands

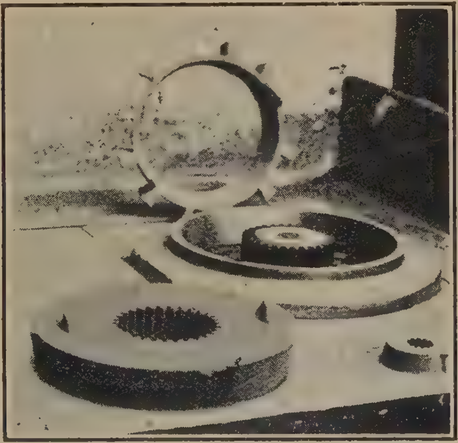


Fig. 21.—Shows the Methods of Making a Water-Meter Gear Wheel.

is worth knowing, and it has been found possible to improve the appearance of castings by the results so far obtained.

[To illustrate the value of experiments on the skin-producing properties of various sands, a small water-meter gear-wheel casting was passed round.] The facing sand used for the teeth consisted of Belfast sand strengthened with a little artificial bond, whilst the other parts were faced with green sand. Fig. 21 shows the method used to make this wheel. No blacking or plumbago was used whatsoever.

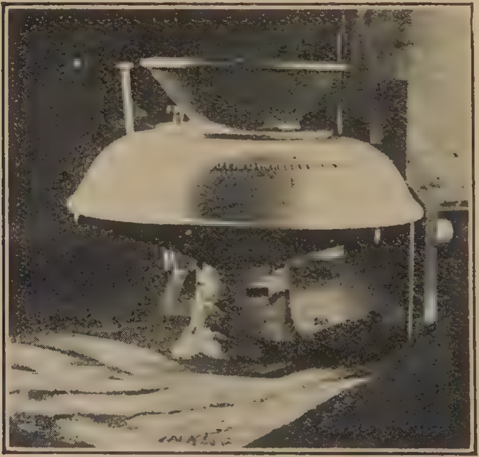


Fig. 22.—The Herbert Sand Mixer.

Blairgowrie sand also furnishes a very good example of the misleading results sometimes obtained when the ordinary "grip test" is used for testing moulding sands. In this case the sand is very strong when green, but very weak when dry. The "grip test," whilst being suitable for green sand, gives little information for sands used in dry sand work.

Fig. 20 is also interesting from another point of view. It has been said that the permeability of moulding sands is of no consequence. If this is a fact it would be interesting to know what caused the blown surface of the section in contact with the clay.

Preparation of Sand for Moulding.

For this work many different types of machines are used as well as hand-mixing, and correct treatment is needed to preserve good properties in a sand mixture. In green-sand work many foundries now use some kind of aerating machine,

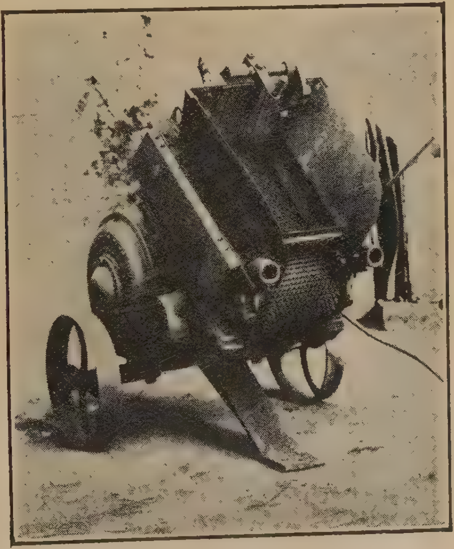


Fig. 23.—The Royer Sand Machine.

and tests have been carried out to illustrate the effect of these. An ordinary green-sand mixture was made up and tested after mixing by hand. The identical sand was then put through a Herbert machine, as illustrated in Fig. 22, and also tested. The product from this machine was then subjected to a light milling, and still further tests taken, and finally the original mixture was put through a Royer machine, as shown in Fig. 23. Table IV gives the test results, from which it should be quite clearly understood that the sand was the same in all these tests, and naturally the moisture content is uniform. In making the test pieces the same degree of ramming was applied to each. From these results it is obvious that little difference exists in the sand put through the two aerating machines. Both have the same bond strength and permeability. However, the sand from these machines is slightly stronger than the same sand hand-mixed, yet the permeability remains the same. In the case of light milling naturally the bond strength is considerably increased with the formation of a closer sand.

TABLE IV.—*The Effect of Various Machines used for Preparing Green Sand Mixtures.*

Method of Mixing.	Moisture content.	Green dropping test in inches.	Permeability in secs.
	Per cent.		
Hand mixed	8.0	2.4	93½
Mixed in Herbert machine	8.0	2.6	92
Mixed in Herbert machine and milled for 5 minutes in light pan mill ..	8.0	2.9	123
Mixed in Royer machine..	8.0	2.54	93½

The value of these machines to the foundry exists in their adoption to production methods rather than to the production of special properties in the sand. A green-sand mould made from aerated sand will be no more open than a similar mould made from hand-mixed sand. The strength of the sand, however, will be slightly increased in the aerated material.

The preparation of dry sand and loam calls for greater care than is usually needed for green-sand work. As a general rule the pan-mill reigns supreme in this sphere of foundry work. Accordingly tests have been conducted to illustrate the effect of milling a dry-sand mixture as regards sand texture, strength in the green and dried condition, and permeability; the results being compared against the same sand hand-mixed and mixed in a machine free from the crushing action of pan-mills. Nearly all of the local bonded sands are obtained from rotten rocks, which have to be milled in order to obtain a suitable sand, and the effect of milling is thus of double importance, especially when clay is added to improve the bond. At the present time such bonded sands are inferior to naturally-bonded moulding sands where the silica-sand grains are coated with clay deposited from water. This inferiority is due to the fact that when milling or mixing sand in the pan-mill, excessive milling is required to get the clay bond uniformly distributed. During this milling operation the actual sand grains are crushed, and their uniform size destroyed. Thus it is obvious that great difficulties attend the production of ideal sands from pan mixing, and it is a very difficult matter to obtain a sand having a good bond strength with low permeability. It would seem that by choosing suitable sands and mixing them in a machine designed to rub the sand grains and bond together without the heavy pressures prevalent in pug mills, a uniform sand would be obtained that would give equal result to naturally-bonded moulding sands. To this end a mixing of dry sand was made in the Rotoil machine, which has been recently placed on the market. This machine is illustrated in Fig. 24.

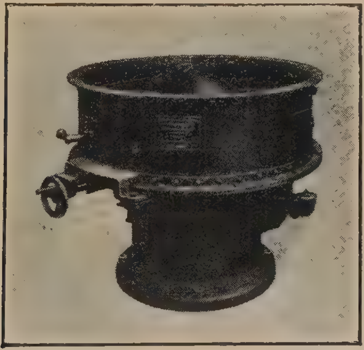


Fig. 24.—The Rotoil Machine.

TABLE V.—*The Effect of Various Methods used for Preparing Dry Sand Mixtures.*

Treatment.	Mechanical grading on dry sample.								Rational analysis.		Moisture. Per cent	Tested green.	Dried at 450 degs. F.		
	Pass 20	Pass 30	Pass 40	Pass 60	Pass 80	Pass 90	Pass 100	Pass 120	Per cent. clay	Per cent. Sand		Green dropping test in inches.	Tensile ozs. per sq. in.	Trans. ozs. per sq. in.	Perm. in secs.
Mixed by hand	91.04	89.60	83.75	71.70	43.84	35.96	33.20	25.79	31.4	68.6	9.6	2.00	201	40½	252
Milled in pan		M	illed	at 10	per ce	nt. m	oistur	e and	dried	down	to 9	per ce	nt. for	testing.	
Mill. 5 min.	91.97	91.00	80.40	72.54	45.00	38.40	35.20	27.55	33.8	66.2	8.0	2.35	219	57	241
10 min.	—	—	—	—	—	—	—	—	—	—	9.2	2.55	391	85½	1,371½
15 min.	92.82	91.38	85.79	73.21	45.99	39.77	38.82	30.22	—	—	9.2	2.73	407	105	1,684½
20 min.	89.95	88.80	83.29	70.94	45.59	39.27	37.79	31.12	38.9	61.1	9.1	2.80	572	105	2,037
Mixed in Rotoil		M	illed	at 12	per ce	nt. m	oistur	e and	dried	down	to 8	per ce	nt. for	testing.	
Machine 5 min.	88.91	87.71	81.70	68.86	40.92	33.74	31.68	25.04	32.4	67.6	8.5	2.25	220½	59	462½
10 min.	88.95	88.12	83.02	69.02	42.05	34.25	32.10	25.54	—	—	8.4	2.50	261	63	430½
15 min.	—	—	—	—	—	—	—	—	—	—	8.5	2.77	239	58½	283
20 min.	91.46	90.42	85.25	72.15	43.32	35.46	32.39	24.65	35.1	64.9	8.4	2.55	252½	80	138½

NOTE.—In each case the mill was loaded to full capacity taking 4 cwts. of sand.

In Table V are given the test results obtained for comparison between hand-mixing, pan-milling and sand mixed in the Rotoil machine. Taking the texture of the sands first, it will be noticed that 25.79 per cent. of the hand-mixed batch passes the 120-mesh sieve. The same sand after being milled for 5 minutes gives 27.55 per cent., which steadily increases up to 31.12 per cent. after 20 minutes' milling. This clearly shows that the sand is being crushed as milling proceeds. On the other hand, the same sand after being mixed in the Rotoil machine shows a decided reduction in the percentage passing the 120-mesh sieve, which points to the fact that the clay bond is being transferred to the sand grains and increasing them in size. In regard to strength of the sand, milling unquestionably increases it, but, at the same time, increases the permeability figure. In this experiment 20 minutes' milling increased the strength of the sand by approximately 160 per cent., and " closed up " the permeability by 700 per cent. This is not a good condition for moulding sand to be in. The sand mixed in the Rotoil machine was increased in strength by 100 per cent., whilst the permeability was made 45 per cent. better. This is a decided improvement over the properties exhibited by the sand before mixing.

At the present time far too many foundries rely upon the addition of ashes, sawdust, horse manure, etc., to make their sands open, and it will be a very good thing for the industry in general when a serious attempt is made to produce naturally-permeable sands. Once a sand is over-milled there is no mechanical treatment that will open it up again, and the only resource is to add artificial venting mediums. It is a very important point to control the milling of dry sand and loam work. In this respect better castings would be produced by using high-class sands that require little milling than by attempting to produce sand mixtures overloaded with floor sand or black sand, which need excessive milling to bring them up to condition.

Fig. 25 gives the results of Fletcher's subsidence test on the effect of milling which confirms the previous remarks. In these tests the dry sand was made from two parts dry-sand floor sand, two parts Loudoun rock sand, and one part sea sand, whilst the green sand was the ordinary facing mixture as used in the foundry. It is very probable that all pan-mills will not crush the sand as found in the last experiment, and the best mills are those having cogged rollers with suitable means of controlling the pressure applied to the sand, and small mills are more efficient in redistribution of the bond than large ones. In most foundries, however, it will be found that sand mixed in the pan-mill for over 10 minutes will be crushed. The effect of an aerating machine, such as the Royer, on dry-sand mixtures is to put the sand into better condition for moulding. Due to the "fluffy" nature of the aerated sand a better impression of the pattern is obtained, and the sand can be rammed closer. If care is not taken, however, this closer ramming can result in making the mould impermeable. This is a case when one would have thought the opposite would have existed.

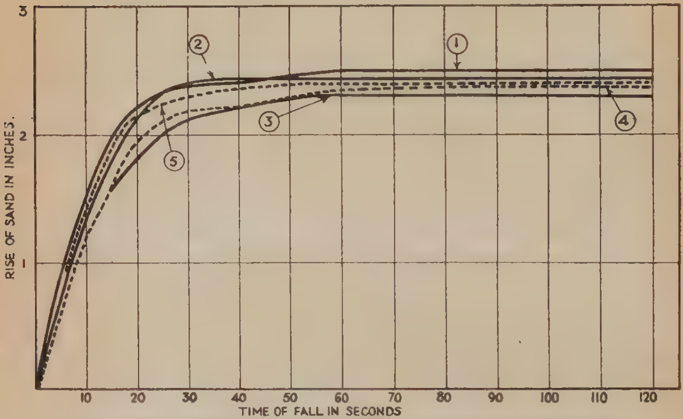


Fig. 25.—Graph, showing the Effect of Milling on the Texture of a Dry Sand Mixture (Fletcher's Subsidence Methods):—1, Hand mixed; 2, pan milled for 5 minutes; 3, pan milled for 20 minutes; 4, mixed in Rotoil machine for 5 minutes; 5, mixed in Rotoil machine for 20 minutes.

Reviewing the work done so far in these experiments the physical properties of the sands and the effect of different mixing machines upon those physical properties are known. If this be the case surely it is a practical proposition to make up moulding sand mixtures that will exhibit desired properties for producing good castings, providing that the moisture content of the sand and the degree of ramming are controlled. For this purpose special apparatus has been designed for foundry use to control such variables and also to enable an idea being obtained of the working

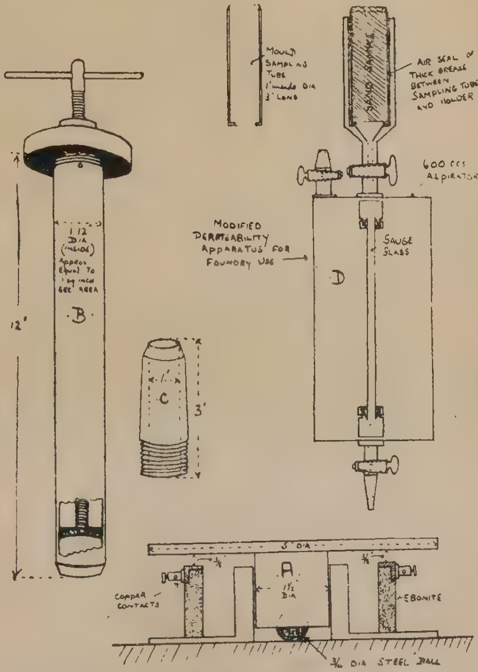

MOULD SAMPLING TUBE 1" inside DIA 3" LONG
SAND SAMPLE
AIR SEAL OF THICK GREASE BETWEEN SAMPLING TUBE AND HOLDER
600 CCS ASPIRATOR
1 1/2 DIA (INSIDE) APPROX EQUAL TO 1 sq inch SEC AREA
B
12"
MODIFIED PERMEABILITY APPARATUS FOR FOUNDRY USE
GAUGE GLASS
D
1"
C
3"
5" DIA
1/8
3/8
A
1 1/2 DIA
COPPER CONTACTS
EBONITE
3/16 DIA STEEL BALL

Fig. 26.—Foundry Sand Testing Apparatus

limits concerning strength of bond, permeability, etc., required of moulds for the most successful production of castings.

Fig. 26 shows the foundry sand and mould testing apparatus, A being a mould hardness-tester, B green dropping-test sampling-tube, C the permeability sampling tube, and D a very convenient form of permeability apparatus for foundry use. The mould hardness-tester consists of a brass base-plate supporting a bearing in which slides a plunger. At the top of this plunger is a loading table, whilst at the bottom is imbedded a $\frac{3}{4}$-in. dia. steel ball. Surrounding the bearing is an ebonite ring having copper contact points at the top, this serving both as a distance stop for the ball penetration, and also for coupling up with a small electric lamp and battery as an indicator when maximum ball penetration has been obtained. The principle of the test is to apply weights to the table until the table rests upon the contact points, and so short-circuiting the current which causes the lamp to light. At full load the ball is imbedded in the mould up to half its diameter, namely, $\frac{3}{8}$-in. The hardness index of the mould under test is expressed by the weight required to imbed the ball, plus 2 lbs., which is the weight of the table and plunger.

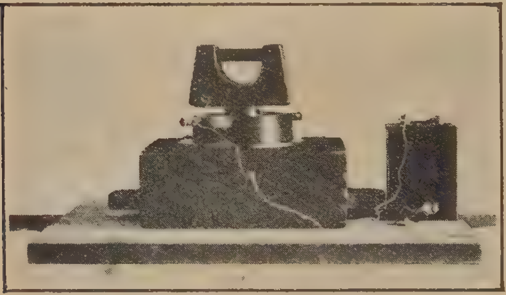


FIG. 27.—MOULD HARDNESS TESTING APPARATUS.

The green dropping-test sampling-tube consists of a brass tube having a knife-edge at one extremity and a cap at the other having a slow thread screwed hole in which works a long spindle attached to a piston. The cross-sectional area of this tube is exactly 1 sq. in. The method of using this tube consists of screwing back the piston to the closed end and pressing the open end into the mould, and extracting a sand-sample similarly to cutting runner and riser "gits" as practised by the moulder. Upon ejecting the sand in a horizontal plane by means of the piston and measuring the overhand after fracture of the sand has taken place, an index of the bond strength is obtained.

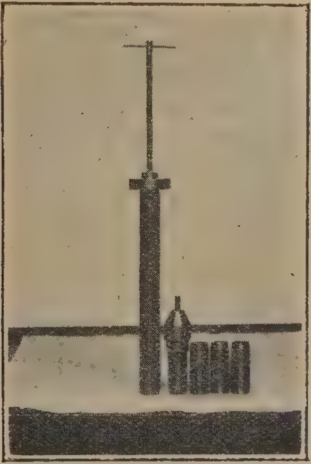


FIG. 28.—GREEN DROPPING TEST AND PERMEABILITY MOULD SAMPLING TUBES.

In the case of the permeability sampling tube C, this is pushed into the mould in the same way as tube B, and a sample of sand obtained for placing in the permeability apparatus described previously. This permeability apparatus is not quite suitable for practical foundry use, and consequently it needs modifying, as shown at D, in Fig. 26. This apparatus consists of a cylindrical aspirator vessel connected to a metal test piece holder. The sand sample is taken by means of the sampling tube, as shown at the top of the sketch, and placed in the holder of the permeability apparatus. A complete operation for testing a green sand mould is as follows.

The permeability sampling-tube is greased inside and pressed into the mould. After extracting, the ends are levelled and the outside of the tube cleaned and coated with grease. The cock at the base of the aspirating vessel is now closed and the two top ones opened. Water is poured into the holder until the vessel is full, as shown by the water gauge. Both these cocks are now closed and the bottom cock opened. The sampling-tube is now placed inside the holder, and the grease coating acts as an air seal. The cock at the base of the holder is now opened and water drops, sucking air through the sand sample. The time taken for the water to drop from the top of the water gauge glass to the bottom is an index of the

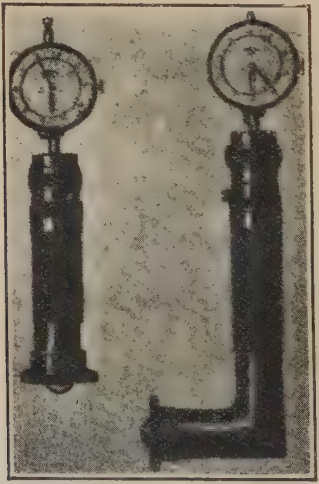


Fig. 29.—The Treuheit Mould Hardness Testing Apparatus.

permeability of the sand. For dry sand samples the mould is sampled in a similar way before drying. After the test piece is dried it is extracted from the tube by hand and the tube greased inside and out, the test piece replaced and put into position on the apparatus.

Fig. 27 illustrates the hardness tester in position upon a small plain top part, and Fig. 28 shows the green dropping-test and permeability-mould sampling-tubes.

In Fig. 29 is shown, as a matter of interest, the only other mould hardness tester known to the author. This is the Treuheit instrument, of German origin. The principle consists of a 4/5-in. dia. ball loaded with a constant weight of about 18 ozs., which is applied to the mould surface, and the depth of indent read off on the micrometer scale at the top. This figure is then converted to the Brinell hardness scale. The instrument has several objections, but space is too limited to describe them.

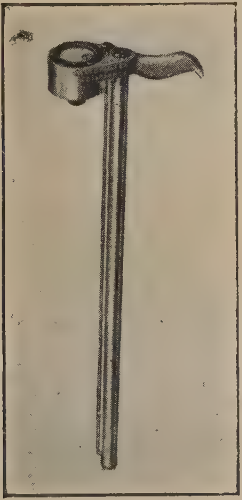


FIG. 30.—THE MCILVAINE MOISTURE METER.

TABLE VI.—*The Effect of Moulding Methods upon Green Sand as Shown by Foundry Sand Testing Apparatus.*

Method of moulding.	Type of casting moulded.	Mould hardness, in lbs.	Green dropping test in ins.	Perm. in seconds.
Hand rammed	Plain top part	14 to 20	—	—
	Side cheek for headstock (ramming on soft side)	16 to 17	—	—
	Plain top part 10 in. deep	19 to 22	—	—
	Plain top part, 10 in. deep	19 to 29	1.66	—
	Plain top part, 6½ in. deep	Edge 22 Centre 36	1.88	73 80
Jolt rammed (Mumford) 8 in.	8 in. lt. valve body (70 jolts). Parting	27 to 31	1.78	55
	8 in. lt. valve body. Parting	32		65
	8 in. lt. valve body. Pattern face	21	—	—
	6 in. reflux valve body. Parting	22	—	—
	6 in. reflux valve body. Parting	21 to 26	—	—
Hydraulic squeezer	Surface box. (1 squeeze)	18 to 20	1.34	45 52
Jolt squeeze (Mumford).	4 in. valve wedge (11 jolts). Parting	22	1.75	115
	4 in. valve wedge. Parting	22		83
	4 in. valve wedge. Pattern face	40	—	—
Sand slinger (Beardsley and Piper).	4 in. valve body. Parting	27	2.12	75
	4 in. valve body. Pattern face	40		64
	4 in. valve body. Parting	9 to 13	2.12	47 50
	4 in. valve body. Parting	27	—	—

Fig. 30 illustrates the McIlvaine moisture meter, which is an excellent means for controlling the moisture content of foundry sands. It reads off the moisture content of any sand heap direct after standardising against a chemically conducted determination.

By the use of these instruments just described it is possible to control foundry sand and moulding conditions to a very near limit. At the same time they can give a very great deal of information relative to the properties imparted to the mould by different ramming methods.

Table VI gives the results of tests conducted on actual moulds made in green sand and rammed by five different methods. In no instance was a mould obtained with uniform hardness. In hand ramming the hardness varied from 14 to 36, but those moulds made by skilled time-rate men were reasonably uniform, as shown by the side cheek for headstock and the plain 10-in. top part immediately below. It was found that in jolt-rammed castings the sand at the parting was much harder than at the pattern face, whilst in the other methods of machine moulding tested the pattern face was invariably harder than at the parting. Fot consistent uniformity in mould hardness, strength of bond and permeability the tests favour jolt-rammed moulds. All the moulds tested produced good castings, and it is quite obvious that actual mould hardness is of little moment in determining whether or not the mould is in the best condition for successful casting production. Strength of bond, as shown by the green dropping test, and permeability, are much more important features, and providing a bond strength of 2½-in. is obtained, together with a permeability as low as possible but not exceeding 80 secs., then for green sand work no fear need be anticipated about defective castings. This result confirms the specification put forward by Smalley for general grey iron castings made in green sand.

In conclusion, the author wished to thank the directors of Messrs. Glenfield and Kennedy for their permission to publish these results, and Messrs. Wyllie, McFedris and Tyrie for their valuable assistance.

DISCUSSION.

Mr. Primrose congratulated Mr. Hudson on presenting one of the finest Papers he had ever heard in that hall, and raised some laughter by twitting the lecturer on his classification of Belfast sand as a Scottish moulding sand. Mr. Hudson had stated that sands dried by heat were not so good unless they were allowed to lie for ten hours. That was surprising to him, for the practice in some American foundries now was to convey the sand by belt from the castings shake-out, dry, and add necessary clay bond, re-mill, and return to moulding machine by a continuous process. Two weeks ago, when he was on the Continent, he saw two foundries where they used silica sand and added a clay bond, and they were heat-treating the sand and clay before it passed on to the process.

Mr. Hudson, in his reply, said he must make an apology for calling Belfast sand a Scottish moulding sand. He did so because it was used extensively in the West of Scotland. Regarding tempering of sand, they had found in making their sand test that when they dried the sand by heat and added the water, the tests were always lower in the dry condition than when they allowed the sand to stand for about ten hours, and then made the test pieces. Why that was so he was not prepared to say. He agreed with Mr. Primrose's statement that in America they were utilising synthetic sands, employing a silica sand, and adding fireclay, but he did not think these sands were quite so good as the sands they used in this country.

Mr. Primrose said that a man who manufactured sand-plant had told him that the sand should be practically dry, and sieved before milling. He said it was necessary to dry it as it went through, and that they could add the bond required for each particular customer, using the same sand. These remarks, of course, apply to repetition machine-made moulds in a foundry having a continuous sand plant.

American Sand.

Mr. Winterton, referring to the remarks about American sand, suggested that the reason why Americans were utilising synthetic sands was that over there much of their sand was of such a silica nature that they had to add something to bring it up to the condition of the sands found in this country.

Mr. Hudson replied that he did not think they would ever get an ideal sand to serve the whole industry. They must just find out the best treatment for the sands they had.

Mr. Arnott recalled that Mr. Hudson's predecessor, Mr. Gardner, had lectured in that hall, and he was glad to see Mr. Hudson carrying on the good work. He thought Mr. Hudson was very courageous in tackling this big problem—one of the most important they were faced with. He would have liked to hear the name of Professor Boswell mentioned, because he thought it was to him that they owed all their recent knowledge of sands. Professor Boswell was a geologist, and it was a geologist's job to tell them what sands were available. They would find in Professor Boswell's book, which he advised them to read if they had not done so, a very good average of Scottish sands among others. One point must be remembered—that sands in this country were very cheap, a matter of a few shillings at the quarry. That was the prime difference between this country and America. In America they had very good sand quarries, but some were very far from the foundries.

Sieving Tests.

He noticed that Mr. Hudson was using the old-fashioned sieves in his tests. These sieves were very much out of date now, and he would suggest to Mr. Hudson that he use the punched copper sieve. The hole in a mesh made of gauze was not round, but square, and sand could be forced through. He could not see any advantage in using as many sieves as Mr. Hudson used, and thought that three or four were good enough to give a good mechanical grading. Regarding the settling test, as Mr. Hudson had pointed out, the clay could be seen in Fletcher's Test; but according to Fletcher only one-third the volume of clay shown was solid clay, hence, in the test tube one-third represented only ten per cent. by weight. Mr. Hudson had not said anything about the grain size of the sands tested for refractoriness. The two sands should be of the same grain size.

Permeability.

Then there was the question of permeability. The number of seconds for the air to pass through the specimen would increase in inverse proportion to the permeability—the more permeable the sand, the shorter the time. Mr. Hudson had said that unfortunately Blairgowrie sand had a high permeability. He presumed that milling increased the time taken in the permeability apparatus, but in that respect it must show reduced permeability. He would suggest that the two decimal places be cut out of the tables for the grading test. In such a test the actual percentage was quite enough. He would like to compliment Mr. Hudson on his excellent photographs. That was a thing they were apt to take for granted, but some of the photographs shown illustrated how much could be explained by really good photographs.

Mr. Hudson had referred to the McIlvaine instrument. He himself had once tried that instrument, and he found that it could not tell any more than a good moulder could tell. It was much used in America, where sand was mixed by unskilled men, who, presumably, did not know whether to make it like porridge or oatmeal. When the instrument showed high or low results, the same thing could have been told by a moulder of good experience. The instrument was not fine enough. When he tested all the heaps in the foundry he could not get any difference. Certainly when they added more water the instrument told them, but as he said, any good moulder could have told them that. One thing had interested him; what degree of uniformity was experienced in successive deliveries from one source? In one research Paper he had looked over the worker had taken samples from the top, middle and bottom of the seam, and when these were compared the differences were often very great. After all, one only needed to look in a sand-bin to find anything from gravel down to the finest of dust. They could not attribute exactly any properties to one particular sand. They might say that the sand had general properties, but they might get very material differences in one delivery That was not to be wondered at in view of the low cost of these sands. The price they paid for them would not pay the quarries, he presumed, even to riddle the sand.

The Subsidence Tests.

Mr. Hudson, in reply to the statement about punched copper sieves, said that there was considerable controversy about these sieves. Judging from the work of the German investigator he had referred to, who passed the sand through silk sieves, he did not think that the results even with punched copper sieves would be any more accurate than with the ordinary wire sieve. Personally he did not like sieving as a test at all. He would much rather use Fletcher's subsidence test. For one thing it was quicker, as it could be done in five minutes, as against an hour in the case of sieving. He had quite an open mind as to the advantages of punched copper sieves over wire sieves. He did not think either kind was accurate. He wished to point out, moreover, that working to fine limits was out of the question in the Paper he had presented. Regarding the question raised about Fletcher's subsidence test, he quite agreed that all the deposit at the top of the tube was not clay, but it was impossible to tell how much was clay and how much was silt. Mr. Arnott had said that one-third of it was clay. With some sands it might be, but with others it might not be. With sand of such a fineness it was sufficient to be considered as clay or silt. Then it had been suggested that milling should be done before testing for refractoriness. He quite agreed, but what value would it have for practical application? The sand had to be used for moulds as it arrived in the foundry. Nowadays the tendency was to use green sand as much as possible. He quite agreed also with the correction Mr. Arnott had made in his statement in regard to permeability, but he thought that the practical man would quite understand his use of the term permeability.

Mr. Arnott had said that the McIlvaine meter was of less use when there were skilled men in the foundry. Again he quite agreed, but in his place they found that most of their defective castings came from the foundry where the work was done by unskilled men, and it was there that the McIlvaine meter was useful. In America the same conditions prevailed, and in America the instrument was in general use. He still maintained that in a foundry where the work was done by unskilled men the McIlvaine meter was useful. Regarding the degree of uniformity in different consignments of sand from the quarry, they had found quite a degree of variation with one sand and another, but this was not the case with all consignments. Some quarries took pains to deliver as uniform a sand as possible. Some quarries had quite good equipment.

Standardised Moulds.

Mr. Laurie said it was obvious that in the short time Mr. Hudson had been with them in Scotland he had put in some very good spadework, and he thought Mr. Hudson would prove an acquisition to the Scottish Branch. He understood that Mr. Hudson was trying to evolve standard sands for standard purposes. Standard sands could only be of the fullest advantage where standard moulds were the order. In general work conditions varied so much. The same degree of ramming would not be suitable for flat work and deep work alike, or the same strength of sand for light as for heavy work.

Influence of Organic Matter.

Dr. Hyman said that there was one aspect of moulding sands which Mr. Hudson had not dealt with, and that was the question of the presence of combustible organic matter in sand. He thought that the permeability of sands had been stretched too much, and that liberation of gas caused by the action of the molten metal on combustible organic matter was the cause of much of the trouble. If one took a sample of sand and dried it at 200 deg. C., and then heated it to the temperature at which it came into contact with molten metal—1,000 deg. C. or more—one often found a loss of about 1 per cent. The liberation of gas which caused this loss of 1 per cent. was probably the cause of many of the failures. He would like Mr. Hudson's opinion on that point.

Mr. Hudson agreed that the question of combustible organic matter in the sand was very important. In Fig. 20, which they had seen showing the refractory test on clay, Blairgowrie sand and Loudoun loam, the metal in contact with the clay was all blown on the surface. They had all heard those who said that permeability in a moulding sand was not necessary. The argument was that casting was done successfully in a chill mould, which had no permeability, and that therefore permeability was not necessary. If one cast metal on to a firebrick it lay quietly. There was no blowing. His opinion was that the blow holes were solely due to the organic matter in the clay being turned into gas. This was a very important point, and permeability was of no importance provided that there was no gas generated from the mould. They must have permeability, and the need for it was greater or less according to the amount of gas formed with steam or the decomposition of organic compounds.

Venting.

Mr. Longden said he knew from experience the need for venting with green said. One had to add to the atural permeability of the sand by vents. When one was engaged in the production of the heavier classes of castings and had to face the problem of the elimination of scabs and other similar defects, one had no room for doubt that this question of permeability was important. If the sand was sufficiently open intexture there was less need for vents. In the absence of vents one was liable to get scabs and blowing in certain classes of work. The problem was simply that of providing an easy mode of exit for the products of the decomposition of part of the bonding materials of the sand. There were one or two points he wished to raise. Mr. Hudson had presented some very good illustrations. In one he showed a slab cast in a mould made with various kinds of sand, and the degree of ease with which these portions detached themselves from the casting indicated their suitability. That was a very good test, but it was necessary to get a little more information about that. In heavier castings, which might be cast in green sand, one would probably have to use a special sand, stronger and more open. It was not true to say that when they had found a sand which gave maximum quality on surface appearance by surface appearance they had found an ideal sand for every purpose in green sand. He had not the slightest doubt, for instance, that Blairgowrie sand would be quite unsuitable for many classes of work on account of its closeness. If only one class of work was being done one could, of course, get a standard sand suitable for that class of work, but in a jobbing foundry there was no one sand that would fill the bill for all kinds of green-sand work. For dry-sand work it was, of course, different. The qualities in respect of sands which had been dealt with in Mr. Hudson's Paper were all of first-class importance. Some time ago, as an alternative to a local silica sand, he had sent for Southport sand. It cost 2s. 6d. per ton on rail at the quarry, but by the time it had reached him it had cost 19s. a ton. That would show that it did pay to consider what their local resources were, and he thought that Mr. Hudson deserved their gratitude for the work he had done for them—work which he thought he might call pioneer work.

Helping the Jobbing Shop.

In his reply Mr. Hudson said that in the case of heavy castings the importance of knowing the properties of the sand was not so great as in the case of lighter work. One very rarely found a heavy casting defective. A good foreman would ensure that all heavy castings went out sound. It was in a jobbing shop where unskilled labour was employed that the value of these tests came in. He felt that Mr. Longden's remarks about the refractory test were quite correct, but, as he had pointed out, Blairgowrie sand was the most refractory sand they had found, yet it was no good for any class of moulding—except perhaps aluminium—because it was so dense. One must adjust the conditions to the job. By watching the ramming effect and controlling the moisture content they had a fair chance of regularly turning out defective castings below 5 per cent. Their aim in his place was to make the sand standard and the moulding methods standard. In the previous week their defective castings were 4.7 per cent., with light castings not over 2 cwts. In their heavy foundry the defectives were about 0.1 per cent. Their total defectives that week on about 150 tons made amounted to about 3 per cent. He thought they would agree that that showed the value of knowing something about their sands.

East Midlands Branch.

MALLEABLE IRON.

By F. H. Hurren, A.I.C.

Within the last four or five years there has been a very considerable addition to the literature on malleable iron. At the Glasgow Convention of the Institute of British Foundrymen in 1925, the author lamented the fact that the scientific and technical knowledge of malleable iron had not progressed to the extent one might have expected. Research work had been neglected, and the little that had been done by private firms at their own expense remained unpublished. Since then many Papers on the subject have been presented to this Institute, or published in the technical Press, and during this present session Mr. A. J. Beck has read a Paper on methods of production. It is now rather difficult to bring up any new matter, although there are many points which are still controversial.

At the Glasgow Convention the present author indicated certain lines for possible research, and it has been a source of considerable gratification to him that the British Cast Iron Research Association has taken the matter up wholeheartedly, and has put in hand an organised and systematic research on many of the problems awaiting solution, much on the lines then suggested. Many useful results have been obtained during the last two years and communicated to the members. These alone would well repay membership of the Association, and further work is still in progress.

Previous to this, the only serious researches published were the work of Emeritus Prof. Turner, Dr. Hatfield, and one or two students of Birmingham University, under the guidance of the former.

It is proposed, first of all, to consider briefly the effect of the different elements in whiteheart malleable iron castings used for general engineering work and conforming to the B.E.S.A. standard of 20 tons tensile, with 5 per cent. elongation on 2 inches. If personal views differ from those generally accepted, the author is open to correction.

Silicon.

This element has been looked upon as the governing factor, and to a certain extent founders have been blind to the fact that other elements may have an influence just as profound, and in certain cases working in opposition. It is recognised that a low-silicon content renders malleable iron more difficult to anneal, and a high-silicon content may give a semi-blackheart fracture and poor physical tests, but the author does not agree that good physical tests are impossible of attainment with a high silicon iron. Undoubtedly, the best all-round results are obtained when the silicon lies between 0.40 and 0.80 per cent. Below 0.40 per cent. silicon, especially with cupola-melted metal, where the sulphur content is often high, difficulties in annealing may arise. In the Rover Works a silicon content between 0.60 and 0.75 per cent. is sought, due regard being paid to the content of other elements.

The effect of silicon is to assist in the precipitation of free carbon. As the content of silicon rises, the temperature at which free carbon is deposited becomes lower. It has been often noticed that where free carbon is precipitated in the early stages of annealing, this free carbon persists, and the elimination of carbon during annealing is slight. In consequence, there is an excess of carbon in the finished casting, mainly in the free or graphitic form. Unless this carbon is distributed in very small nodules, weakness may result from the presence of flaky graphite. This effect is modified by the percentage of carbon present in the original casting, by the rate of solidification of the hard casting, and by the rate of cooling after annealing.

Carbon.

It is generally acknowledged that the carbon in the hard casting should be almost entirely in the combined form, as the presence of graphitic carbon introduces a risk of flakes of graphite being formed during annealing, with consequent loss of strength in the annealed material. What is not so generally realised is that the carbon content in the hard material may vary within very wide limits. The author has had deliveries of malleable pig-iron with a total carbon content as high as 3.7 per cent., and other supplies with under 3 per cent. carbon. The length of time required for annealing is often considered to be a function of the silicon content, but experience has shown it is determined by the carbon content. It will be realised that the best all-round physical tests are largely dependent upon the carbon content of the annealed material, and the form in which that carbon is distributed. Where a soft, easily-machinable material is required, and very high physical tests are not essential, a short anneal of a high carbon material, followed by slow cooling, will give the desired results. Where high physical tests are required, the elimination of carbon must be considerable, and the composition of the annealed material approximate to that of steel. Any free carbon present must be in a finely divided state and not as flakey graphite.

Elimination of carbon appears to depend to a large extent on time of annealing; the longer the annealing time, the greater the elimination. Experience has shown that the best mechanical results are given by material having a low-carbon content after annealing, with the proportions of free and combined carbon approximately equal. It would appear from this that with a low-carbon pig-iron and a short anneal, results would be obtained equal to a medium-carbon pig with a longer anneal. If such were possible it would be a decided step forward in the cheapening of production of malleable castings. Unfortunately, the problem is complicated by the fact that repeat tests taken under apparently identical conditions of casting and annealing do not show identical physical properties. The question of slight variations of casting temperature, rate of solidification, and rate of cooling after annealing, to say nothing of variations in composition of packing medium, exercises a profound effect on the final result. It has been stated, and to a certain degree proved, that the grain size of the hard material persists after annealing.

Grain Size Persists.

The finer the grain size in the hard casting, the finer the grain size in the annealed casting. The physical test-results increase as the grain size decreases. It naturally follows that a casting in which the metal has set quickly will give better test-results than one which has solidified more slowly. This more rapid solidification occurs in thin sections, and may be effected by casting at a higher temperature, and by the use of chills. An instance of the former effect may be proved by casting two bars from the same shank of metal, one bar being of 1 in. × ¼ in. section, and the other bar 1 in. × ½ in. section. Although they may be annealed together under similar conditions, and the ½-in. bar annealed for a period twice as long as the ¼-in. bar, the latter will give the better physical tests.

Alternatively, the effect of chill may be determined by casting two bars of identical section, one in sand and the other in a chill mould. After annealing together, it will be found that the chill-cast bar invariably gives the better results.

In 1925 the author stated that for the best general results the total carbon in the hard casting should lie between 2.9 and 3.2 per cent. Recent research has tended to prove that statement was correct, and further tests have shown that the least trouble is experienced in obtaining soft ductile material, annealing under ordinary commercial conditions, when the total carbon in the hard casting lies between these limits. Due regard must be paid, of course, to the other constituents.

Sulphur.

The effect of sulphur has been very carefully studied by E. R. Taylor, and published as a Carnegie Scholarship Memoir by the Iron and Steel Institute in 1925. This Paper is well worth studying. Taylor shows conclusively that the ultimate stress and yield point are not appreciably affected until the sulphur content exceeds 0.65 per cent., but both elongation and bend test results fall with increasing sulphur. There is a rapid fall in the elongation up to 0.3 per cent. sulphur. There is also a rapid fall in the bend test up to

0.6 per cent. sulphur, when again the decline becomes gradual.

A sulphur-content of 0.65 per cent. is not often found in commercial malleable castings, and certainly nothing approaching this percentage should be present. In ordinary day-to-day working the maximum sulphur content should not exceed 0.35 per cent. in the annealed casting, and there is something wrong either with the melting practice, the coke, or the pig when this figure is exceeded. In connection with this matter, it is well known that sulphur tends to retard annealing. A combination of low silicon and high sulphur will give a material which is impossible to anneal satisfactorily. The author had a case some years ago, in which the silicon was 0.42 per cent., and the sulphur 0.45 per cent., and the castings were unmachinable after 500 hrs. annealing.

There has been much talk of late on desulphurisation. In works practice there should be no necessity for desulphurising. Pig-iron makers ought to be able to supply material reasonably low in sulphur, and any excessive gain in sulphur during melting, shows cause for an overhaul of the melting practice. However, one should always be ready to try out new ideas, and the author conducted numerous experiments on desulphurising, without any definite advantage accruing. One of the cheapest desulphurising agents is commercial soda ash, and several tests were recently made with this. In the first test, 3½ lbs. of soda ash were added to a ladle of 3½ cwt. metal. A very violent boiling action occurred which lasted five or six minutes. When this subsided and the very fluid slag which formed had been removed, it was found that the metal was too cold to pour, and castings and test pieces were misrun. The sulphur had been reduced from 0.247 per cent. to 0.199 per

TABLE I.—*Influence of Soda Ash Treatment on Tensile Strength of Whiteheart Malleable Iron.*

	Elongation. Per cent. on 2 in.	Ultimate stress. Tons per sq. in.	Yield point. Tons per sq. in.
Before	8.5	22.4	16.05
After	7.0	20.8	15.12

cent., and there was a very slight loss of silicon. In further tests only half the quantity of soda ash was used, namely $1\frac{3}{4}$ lbs. to $3\frac{1}{2}$ cwt. metal. Test bars were cast before and after treatment, and all bars annealed together. The loss of sulphur was very small, from 0.295 per cent. before treatment to 0.282 per cent. after. The tensile tests were as set out in Table I.

It will be seen that the mechanical properties were not so good after treatment, and as repeat tests gave similar results, the process was discarded.

Phosphorus.

A very exhaustive research on the influence of phosphorus was carried out some few years ago at Birmingham University, under Prof. Turner's guidance, and it was proved quite definitely that phosphorus in excess of 0.20 per cent. had a very harmful effect on the physical properties. As the ordinary commercial brands of malleable pig rarely contain more than 0.10 per cent. phosphorus, trouble from this source is very unlikely. Some time ago this effect of high-phosphorus content was brought home to the author very forcibly, when by error, a high-phosphorus pig was used in one day's charges. The annealed castings were soft but very brittle, and would break by dropping on a stone floor. The phosphorus content in the casting was 0.40 per cent.

Manganese.

The effect of manganese in whiteheart malleable iron has been studied by E. R. Taylor, and the results embodied in a Paper read at the Sheffield Convention of the Institute of British Foundrymen in 1927.* He shows the effect on the physical properties of increasing quantities of manganese, with sulphur remaining constant, and the results are aptly summarised in the statement that " the best results on an ordinary anneal are obtainable when the manganese is approximately 1.7 times the sulphur, whatever this may be." The importance of this statement has been very definitely impressed upon the author recently. The commercial brands of malleable pig contain percentages of manganese varying from 0.05 up to 0.60 per cent., the general run being in the neighbourhood of 0.15 per cent.

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*Proceedings Inst. Brit. Foundrymen, Vol. xix., p. 267.

The accepted theory of the effect manganese exercises during annealing, is that excess retards annealing owing to the formation of manganese carbide. This is a very stable compound, and may not break down during the annealing process. It is also considered that the manganese combines with sulphur, forming manganese sulphide, which does not retard the precipitation of carbon.

Nickel and Chromium.

Additions of nickel or nickel and chromium are still somewhat in the experimental stage. The chief effect nickel and chromium have on annealed malleable iron is to cause the temper carbon to precipitate in very small spots, which naturally has a toughening effect on the material. Chromium appears to have an action similar to that which it exerts on grey iron, namely, to increase the stability of the combined carbon necessitating an increase in the annealing time.

Influence of Annealing Time.

Practice varies in different foundries, but the average appears to be 30 to 40 hrs. heating up to annealing temperature, maintaining that temperature for approximately 100 hrs., followed by a slow cooling down to black heat, after which the cooling may be more rapid.

The results obtained from personal experiments, examined in conjunction with those of other workers, tend to show that for a definite composition of the hard material, time mainly affects the elongation and angle of bend. A short anneal, that is about 60 hrs., will give a material having certain physical properties, in which the ultimate stress is in the neighbourhood of 25 or 26 tons, with an elongation of 2 or 3 per cent. An increase of annealing time to, say, 100 hrs., only very slightly reduces the ultimate stress, but increases the elongation to 5 or 6 per cent. Annealing for 120 hrs. again has little effect on the ultimate stress, but again increases the elongation. Excessive annealing then seriously reduces the ultimate stress, often accompanied by a reduction in elongation.

From this it may be deduced that for a definite composition of the hard material there is a definite time factor for annealing to obtain the best all-round physical results. It seems feasible, therefore, that the variations obtained in tests on annealed material are due more to irregularity of composition in the hard casting than to variations in annealing time and temperature. If it was possible so to melt iron that all the hard castings approximated very closely to the same composition it is believed that all those castings, when annealed together, would show approximately equal physical results, assuming freedom from casting defects. There must be some tangible reason for the variations now found and the differences between one casting and another, even when annealed under apparently identical conditions. To obtain bulk supplies of molten metal of the same composition is difficult of attainment with the cupola, but should be possible with the air-furnace or the electric furnace, and it is along these lines that better uniformity of result will be attained. The cupola is undoubtedly the cheapest form of melting unit for large tonnages, but if a more regular product is possible with other forms of melting, the gain in that direction may more than counterbalance the increased cost of melting.

Troubles Peculiar to Malleable Castings.

Distortion is a trouble with which everyone connected with the malleable trade is familiar. It may be due to awkwardness of design or to methods of packing. There does not appear to be any royal road to cure this evil, but it can be minimised to a certain extent by care in placing work in the ovens, and by the use of packing strips or blocks cast to the necessary shape and fixed in the hard casting by wedges or clamps.

Another complaint which crops up from time to time is the presence of hard spots or patches where a runner or riser has been ground off. Provided this is not too deep-seated, it has been found that heating up to about 800 deg. C. for three or four hours, followed by slow cooling, generally eradicates the trouble. The local heat generated during "hobbing" may become excessive if there is a large amount of metal to be removed, or heavy pressure is put on the grinding wheel. This has the effect of reversing the annealing process, leaving local areas higher in combined carbon. The subsequent short period of heat, followed by slow cooling, gives a return to the soft state. Provided this treatment is carried out with reasonable care no ill-effects are likely.

One of the most puzzling troubles encountered is the cracking of castings during annealing. Suddenly, and without apparent reason, castings after annealing have been found to have cracks in various places. Some of these occur in the centre of thick sections, often starting from the interior edge and radiating outwards, but not completely through the section. Some cracks appear at the junction of thick and thin sections, others as Y-shaped or star cracks in the middle of a plain section, no part of the crack reaching to an edge of the casting. These latter often have the appearance of cold shuts, and invariably show on the lower surface of the casting as cast. Hard castings have been sand-blasted, examined with a magnifying glass, and tested in other ways to prove entire freedom from cracks, yet after annealing cracks are easily apparent. The troubles have occurred in the Rover Works at irregular periods, sometimes three or four years apart.

Investigating this matter very closely, the author noticed recently that each period of trouble occurred when the manganese content in the iron was lower than usual, and he inclines to the opinion that this is the primary cause of the trouble. It is well known that the manganese should be 1.7 times the sulphur content for the whole of the sulphur to form manganese sulphide. If sulphur is in excess of this ratio, some of it will combine with the iron to form iron sulphide. This tends to form thin threads in the metal, which are lines of weakness, and may develop into cracks on cooling. It has been proved that iron sulphide, or a combination of ferrous sulphide and manganese sulphide, has a lower melting point than manganese sulphide. At the high temperature of annealing this may give rise to local areas of weakness, with a consequent crack developed during the cooling-down period.

In addition, manganese has the effect of retarding the annealing by holding up the precipitation of carbon. In these cracked castings, in addition to a very low manganese content (under 0.10 per cent.), the elimination of carbon has proceeded more rapidly than would have been expected. In many instances, after only 100 hours' annealing, the total carbon has been reduced to 0.60 per cent., and in certain cases even less. Is it not possible that this rapid elimination of carbon, in conjunction with the formation of threads of ferrous sulphide, causes severe internal stresses, and the metal opens out where the threads have formed? This idea is postulated as a possible explanation of the trouble. The experiments are not yet completed, but it is a curious fact that, so far as at present can be said, any tendency for cracks to develop during annealing ceased when the manganese content was raised.

Many of the factors governing the successful production of malleable castings are still obscure, and until these are thoroughly understood, malleable iron will continue under the reproach that it is not an entirely reliable material. This should not be.

It is felt that only collective and concerted action will ensure the greatest good, and this may be best attained by all the malleable-iron manufacturers giving their support to the British Cast Iron Research Association.

DISCUSSION.

Mr. Blades expressed his pleasure with the Paper which had been given; there was no doubt that the author had gone fully into his subject. He would like to have further information regarding desulphurising with respect to hard spots that had been experienced; did not that depend to a large extent on the chemical composition of the metal? Was not the cracking, which occurred during annealing, due to too rapid cooling after the anneal? Could any information be given about the carbon content varying from the skin to the core similar to sulphur, and could any definite particulars be given regarding annealing temperatures?

Mr. S. H. Russell remarked that whilst his knowledge of malleable iron was only very slight, he would like to ask whether in the use of soda ash as a desulphurising agent it was a failure when there was no slag on the metal? Had Mr. Hurren any experience of slag traps or of spouting containing a high percentage of soda ash?

Mr. E. A. Peace was of opinion that the carbon content depended on the method of operating the cupola, and the grain size depended on the silicon content, this being a great factor in the temperature of annealing. He had never had any experience of cracks radiating from various centres, and no one yet had been able to produce manganese sulphide in the presence of iron in theoretical quantities.

Mr. Goodwin pointed out that malleable iron was a very sensitive material, and only those engaged in the industry knew to what extent. He had made a few experiments with nickel and chromium, and found that with the addition of 1 per cent. nickel it made a material difference.

Mr. C. H. J. Beck raised the question of distortion before and after annealing. With respect to the trouble of cracks during annealing, he had had only one experience, which was before the anneal, and was due to an unremoved core.

Mr. Hurren, replying to the discussion, said the difficulty of the hard spots mentioned was not due to chemical composition, by altering which would eliminate the difficulty. It was one of the difficulties that arose in the method that castings had to be run and fed with risers, the difficulty being overcome as he had outlined, due care being exercised. In regard to desulphurising, one could say that soda ash was a qualified success, but when no slag appeared on the metal its action had failed. To the question of the percentage of the sulphur content from the skin to the centre, Prof. Read found sulphur higher in the skin than the centre. The author agreed that the carbon content varied according to the method of operating the cupola; if the cupola was not operating as it should, there was always an increase of the carbon content Bend test of 60 deg. was better for machining than a test of 20 deg. With respect to the difficulty of distortion, his experience was that the percentage before annealing was very low. After annealing, the worst castings with this trouble were plain, flat discs. In regard to annealing temperatures, it was their practice to heat up for 36 hours till a temperature of 960 deg. C. to 970 deg. C. was reached, remaining at this for 96 hours, when it was allowed to cool down slowly 20 deg. per hour to 750 deg. C., after which no ill effects in cooling quickly were experienced.

Newcastle Branch.

CUPOLA PRACTICE.

By W. H. Poole.

Historical Notes.—To trace the development of the foundry cupola from its early stages is in itself a subject for a separate lecture. The following comments of interest are sufficient to indicate its origin. In the first place, the direct extraction of iron in the malleable state from ore was a beginning of the development of the blast furnace, and then the cupola. The ancients found means of extracting from the ores metal in a malleable or workable form. To this day the natives of India, Borneo, and Africa, and even in Europe, still practice the primitive method of extraction.

This process can be said to be the direct process, in a like manner the modern blast furnace is regarded as a means of obtaining pig-iron from ores. The early plant used was simple, consisting of the furnace, and a blowing plant. The charge was iron ores and the fuel, charcoal.

The furnace of this primitive type was usually a small hearth, 2 to 4 ft. high, circular in form. The width at the bottom across the hearth 10 to 15 in., and 6 to 12 in. at the top. Clay was used to build up the stack. Two openings were at the furnace bottom, one for the blast pipe and the other to tap out the slag. After drying the furnace, two earthern pipes or tuyeres, about 12 in. long and 1 in. internal diameter, were placed side by side at the opening, projecting 2 in. into the furnace interior, and some 3 to 4 in. from the bottom.

The bellows or blower was connected to the tuyere. After stopping the slag hole with clay, the furnace was half filled with charcoal and fired. Then the "blast" was applied, and it is interesting to note that the smelters attached much importance to kindling the fire at a proper height above the tuyere before charging the ore. Ore and charcoal were charged, and after 4 to 6 hours the blow was complete. The malleable mass of reduced iron was withdrawn from the hearth by breaking down the furnace front. This metal was next worked by hand into tools, etc.

The Catalan furnace was much used in the early days in Spain. The plant was blown by a "trompe" in the early types, being made from a hollow tree with suitable openings for the incoming and outgoing air. The air was set in motion by a fall of water down the hollow tree. With an improved box form of this blower the iron was obtained in the form of a malleable metal, and was extracted and worked under the hammer.

The Osmund furnace more nearly approached the cupola. The furnace was built with a restricted shaft just above the tuyere. This furnace was operated in Sweden, using charcoal for fuel, and the resultant malleable metal was also worked by hammering.

From this stage the furnace size was increased, the shaft extended in height, the tuyeres raised, more charcoal used, and then commenced the production of molten metal. It is of interest to note that the condition said to be favourable to the formation of cast iron was prolonged contact of the reduced metal with carbon at high temperatures.

In these early direct-process furnaces, the smelter was considered a poor workman if he produced *molten iron*, and there are records of fines being inflicted on such occasions. It can be taken that following the reduction of the ores to form malleable metal, the "Bloomery" furnace later developed into the true progenitor of the blast furnace. Castings were for a long time made from the blast furnace, and for a long time the founding art went hand in hand with actual pig-iron production. Pig-iron was made in this country in the fourteenth century. In the year 1543 Ralph Hogge, at Bluckstead, in Sussex, made a cast-iron cannon. Such firms as Carron, and Newton Chambers, had very early associations with the art of founding.

Réaumur (of malleable iron fame) was one of the first to adopt cupola melting, *i.e.*, melting pig-iron with blast and fuel in a separate furnace. This was in 1750. Wilkinson, in 1794, brought out a patent for a cupola which is similar to many modern plants in its construction. Some writers insist that the remelting of pig in a separate plant resulted from the uncertainty of results of using direct metal into castings, *i.e.*, pig-iron as tapped from the blast furnace, but probably the need for a smaller, quicker melting plant influenced cupola development. Moldenke has given an interesting historical survey of this development, and suggested that the name "cupola" was derived from the German "Kuppel," and named after a furnace in use in 1454 which had above the hearth a chimney terminating in a kuppel or cupola fixed for better charging purposes.

Early Cupola Patents.

As a matter of interest the author has examined the patent specifications from the earliest year in the Keighley Library, and was interested to note that round about 1859 the following patents were taken out on interesting lines:—(1) Patent for injecting gas tar, oils, or resin through the tuyeres of the cupola; (2) steam injection at the tuyeres, claiming high temperature of reaction; (3) another patent claimed results from more than one row of tuyeres, and cited two or more rows which could be worked independently from separate wind boxes. The upper row had to incline downwards and the lower row upwards. The stack of the cupola should be double the diameter of the part into which the tuyeres opened; (4) in 1860 a patent was taken out for the utilisation of waste gases from the cupola to dry cores and moulds; (5) 1863 brought a patent for a receiver to the cupola; (6) in 1865 a cupola furnace was patented in which the lower portion of the furnace was formed of perforated slabs of refractory material, through which air was forced or induced from the atmosphere by the use of steam jets; and (7) in the same year a patent for a hot-blast cupola was taken out.

In Krigar's cupola, which was worked in 1860, the shaft was square or oblong, and parallel in length. Air was delivered by two mains. The air entering the passage became heated from the hot brickwork and passed into the melting chamber through two long slots in the roof, extending right across the width of the hearth. Unfortunately, the heat extracted from the metal in the furnace well resulted in cool iron. The coke consumption given was 1½ cwts. per ton of iron melted exclusive of bed. Ireland's cupola was in use in 1866, from which 220 tons of metal were melted from two cupolas in 10¾ hours with a coke consumption of 1¼ cwts. per ton iron charge, exclusive of bed. This cast an anvil block weighing 205 tons. A third interesting plant was Woodward's steam jet cupola, wherein the air was drawn through openings placed radially like ordinary blast tuyeres.

Volume or Quantity of Blast.

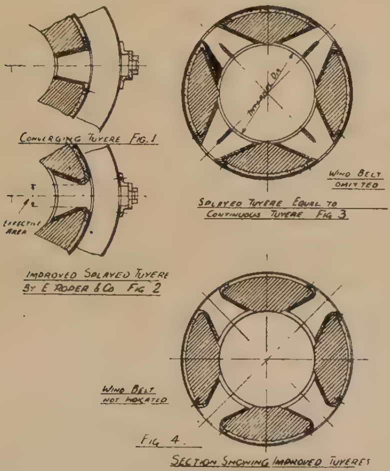
The quantity of blast to be supplied will depend directly on the fusion coke required for the melting capacity of the cupola. It is necessary to put it this way, as some people think they can always get hotter metal by using extra coke, but this is only possible where the cupola is normally worked below the capacity of the melting zone area, or the blower too large for its work.

Hot melting is a result of good design and correct wind balance, by this is meant a blast pressure which will give as far as possible, an even pressure across the bed, and a volume of blast which will consume the correct amount of coke per hour for melting the class and quantity of iron at the highest rate, the melting zone area of the cupola in question will stand without undue wear of the refractory lining.

It is the function of the tuyeres largely to give this balance, and though founders are generally told to work to such and such a ratio tuyere area to tuyere zone area, these ratios are misleading, unless taken in conjunction with the height of the charging hole above the tuyere level. It is impossible to standardise this ratio unless the ratio of the diameter at zone to the height from tuyere to charge door has just been standardised. Cupolas are working satisfactorily on all ratios, from 1:4 to 1:20.

To illustrate this, a cupola of large internal diameter having converging tuyeres (Fig. 1) of, say, 3 ft. 6 in., with a charging hole 7 ft. above the tuyeres (a ratio of 2:1); tuyere area to melting zone area of the ratio 1:20 and a blast pressure in belt of 1½ lbs. gave fairly good results. Modern tuyere practice in such a case, with tuyere area to zone ratio 1:5 would give poor results, with the same blowing conditions.

In the case of the converging tuyeres, the power consumption was high, and the general working conditions far from satisfactory. The pressure of blast (1½ lbs.), whilst high in the belt, would rapidly fall inside the cupola, but sufficient pressure would be available at the mouth of the tuyeres to penetrate into the centre of the coke bed.



Figs. 1 to 4.—Tuyere Arrangements.

On the other hand, a well designed cupola with a height of charging hole above the tuyeres 4½ to 5 times the zone diameter, and an area of tuyere to zone area of say 1:6, with tuyeres as Fig. 2, would give much better results with a blast pressure of $\frac{7}{8}$ lbs. per sq. in., and excellent melting conditions. The pressure of blast in this instance would not fall away rapidly in the cupola, and would soak through the coke bed, as the chief resistance is in the cupola itself, enabling the tuyeres to be a larger size and well splayed. The cold blast is playing on a larger area of hot coke, preventing excess slag formation through chilling, and the consequent restriction of the effective tuyere area. The power consumed by using blast at 7 to 8 lbs. against 1½ lbs. for equal volume will be less than half.

Pressure of Blast.

The pressure gauge records the resistance to the air entry, and not the amount entering. The pressure of blast should be such as to give as near as possible an even pressure across the bed at the tuyeres, and will obviously vary with the internal diameter and correspondingly with the melting capacity. This variation is generally from ½ lb. on small cupolas, to 1¼ lbs. on larger furnaces up to 12 to 14 tons per hr.

The melting rate should be fixed from the melting zone cross-section area, taking into account the class of metal to be melted and the fusion coke allowance. As a general average, 2 cwts. coke per ton fusion coke is ample. This works out at 160 sq. in. melting-zone area per ton melted per hour.

Volume of Blast.

This varies from 30,000-36,000 cub. ft. per ton per hr. of metal melted, based on the above figure. Some allowance for resistance and losses in pipe line, etc., should be made. It is always advisable to have, where possible, a speed regulation for fan and blower, so that adjustment may be made. With a high pressure fan it is most important to have the resistance in the cupola correct, that is in the tuyeres and cupola itself, by having suitable internal diameter and charge door height.

Whilst part resistance can be had in the tuyeres, the main resistance should be in the cupola itself, as this is more constant if the cupola is kept uniformly charged, and will give a natural pressure at the cupola bottom, and not a spotty pressure as produced by tuyere restriction, to produce resistance.

Fig. 3 shows a cross section of a cupola fitted with splayed tuyeres. Such tuyeres should only be applied to cupolas where the resistance is in the body of the cupola, otherwise there will be a tendency to creep up the sides of cupola with loss of penetration. The brickwork is cut away on this section, and the brickwork above carried on the tuyeres. The type shown in Fig. 4 is, in the author's opinion, to be generally preferred.

One Row or Two Rows of Tuyeres.

This question has been much debated, but from personal experience it can be stated that it is a question of the internal diameter or cross sectional area in the tuyere zone. In a cupola of relatively large internal diameter, such as straight-lined cupolas, one row will be as efficient as two, and sometimes an advantage, as it reduces the height of the melting zone, and so saves coke.

With a taper lining, with reduced diameter at the tuyere-zone area, two rows are desirable, so that part of the cold-blast is introduced in one cross section, and part on a cross section higher up, the gases formed by the lower level blast being hot by the time they mingle with the top tuyere blast, and so preventing serious chilling of the slag and descending metal. There is a limit to the quantity of air that can be introduced at one cross section, and this limit is that required to give the maximum combustion in that particular zone or level.

It is important in introducing a second row of tuyeres that the height of the second row should be kept so that the air is introduced just above the hottest part of the bottom zone. The practice of fixing the top row too high is in effect to produce two distinct melting zones, and so lose the zone concentration of suitably placed tuyeres. Two rows obviously increase the height of the melting zone. It can be taken that if the combustion set up by one row is below the maximum, a second air volume introduced correctly at a higher point is of distinct advantage—giving actual combustion in the higher zone, in such a manner that it merges into the lower heat zone.

Much is claimed for three rows, and the use of spiral tuyeres placed up the stack is again receiving attention. As regards three rows, the author has never in his experience found any advantage from the top row. One row of tuyeres in a suitably designed furnace, equipped with the desired blast supply, is generally to be preferred. The addition of supplementary air above the melting zone, with the object of converting any CO to CO_2, has been frequently tried in the past, but has proved of little use—probably from the simple fact that the small tuyeres that it is necessary to use are so readily blocked with slag. The small tuyeres are used on account of the comparatively small quantity of air to be admitted, and the wide distribution aimed at in introducing the air.

A Comparison of High-Pressure Fan and Root's Blowers for Foundry Cupola Melting.

Fig. 5 is intended to show the essential difference between the above, that the former induces the air it delivers, while in the latter the air gravitates into the blower casing, is enclosed by the rotating drums, and discharged through the outlet. As a definite volume of air is discharged (neglecting slip) for each rotation of the drums, it is known as a *positive blower*. In the case of the *fan blower*, if the blast pipe leading from the fan to the cupola is closed by a regulating valve, the fan is prevented from inducing air and runs light, and the only work done is that the air inside the casing is disturbed, and raised to a pressure depending on the speed of the impeller.

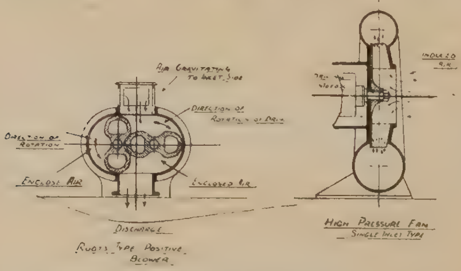


FIG. 5.—SECTION BLOWER AND FAN.

The fan is therefore running light when the blast valve is closed, only about $\frac{1}{3}$ of the normal working power being absorbed, the fan being normally loaded when the area of the opening of the valve, or the subsequent resistance in the cupola, is sufficient to allow the correct volume of air to pass for which the fan is designed. These conditions are reversed with the Root's-type blower, and if the blast valve to cupola is closed, the blast would have to be exhausted through a relief valve fitted between this and the blower.

The air being forced through this relief valve (which is loaded above the working pressure) more than the normal working power is absorbed, and the blower is running light when the valve is full open and no subsequent resistance offered to the discharging blast.

Volume and Pressure.

The pressure of blast delivered from a fan depends on the perifery speed of the impeller, and if insufficient resistance is offered, a large increase in the volume of air delivered takes place, the fan endeavouring all the time to deliver this at the pressure corresponding to its speed. This would seriously overload the driving mechanism, upset the correct working of the cupola, the worst running condition for a high pressure fan being when delivering blast against no resistance. It follows therefore, that a correct resistance is essential for a fan where a specific volume and pressure of blast is required as in the foundry cupola.

The Root's blower, however, delivers a constant volume of blast under all practical conditions, as the drums revolve at a definite speed and sweep out of the casing a constant number of cub. ft. of air per minute, and it is the pressure alone that varies, this variation being directly as the resistance offered to the blast.

The Application.

The points emphasised above, give the key to the correct installation of either of these units. Obviously any leakage in the blast mains, or from badly fitting sight hole castings, etc., on the cupola wind-belt, will result in a high power-loss with the fan installation, and a loss in the melting capacity due to a fall in the blast-pressure with the Root's blower, as this blast escapes to the atmosphere against no resistance. This also applies to the careless opening of the sight holes for poking, etc., which may seriously overload a direct-motor-driven fan. To prevent this, sight hole castings should be fitted with double lids, a small one for poking and a large one for cleaning the belt when the fan is not running.

This power-loss does not occur on a Root's blower installation, as the opening of the sight holes takes the load off the blower, but it more rapidly reduces the pressure of blast supplied to the cupola than with a fan, as the latter absorbs more air to make up the deficiency. In either case, therefore, the suggestion *re* sight holes is equally valuable, and leakage in pipe joints, etc., should not be allowed.

Cupola Design and Resistance.

While a cupola designed for a fan will give equally as good results with a Root's blower this is not reversible, as some cupolas giving fairly good results with the latter are totally unsuitable for a fan. A cupola with a low charging hole, and numerous small tuyeres, supplied with blast from a Root's blower, could be arranged to give fairly good results (although not practice the writer recommends) because the correct volume would be delivered, and any resistance of the tuyeres due to slagging, would raise the pressure which would help to keep them free. With the blast supplied with a fan, however, the pressure would remain constant at that corresponding to the speed, and less and less blast would be supplied as the restriction increased, resulting in slower melting and less driving power being absorbed.

The tuyeres in this case would have to be kept free by poking, and the constant variation in volume of blast supplied, would lead to very indifferent melting.

Which Unit is the Best for the Purpose?

The answer is that while the Root's blower is a safer unit to instal by inexperienced people, (particularly on many existing cupolas which are not remodelled) the fan is equally as good if the cupola and blast pipes are suitably designed; is cheaper to instal and repair, equally efficient, and takes, if anything, less power to drive. The fan is more efficient when controlling the melting rate with the valve, as with less air delivery less power is absorbed, whereas the volume and power absorbed is constant in case of Root's blower, unless a special bye-pass valve is arranged to discharge the air against no resistance.

By the cuopla being suitably designed, it is chiefly meant that the resistance necessary to obtain the requisite pressure of blast is obtained in the cupola itself. This is done by having the charging hole at the correct height to give the pressure (or resistance) required, making the tuyeres of ample area, and splaying these on the inside, so that partial slagging does not interfere with the effective area.

All unnecessary resistance between the fan and the inside of the cupola such as sharp bends, long blast pipes, etc., should be avoided, as these all absorb power which should be available for delivering the blast to the cupola. These are also the correct conditions for a Root's blower installation, but whilst essential for success with a fan, are not so necessary with Root's blower, owing to its positive action, as previously explained.

Control.

As it is not usual to make provision for varying the speed of the driving arrangement for the Root's blower, to control the rate of melting in the cupola, the volume of blast supplied is reduced by partly closing the blast valve in the connecting pipe, and this should be fixed up to the cupola. Part of the blast is then blown out of the relief valve, or all of it, if it is necessary to stop the cupola suddenly. Control of the cupola with the blast valve, therefore, gives no economy in power consumed when working with a reduced melting capacity in the case as above, as the full amount of blast is still delivered by the blower, and at a higher than normal pressure, as part of it is delivered through the relief valve, which is loaded slightly above the working pressure.

The writer therefore suggests an exhaust valve fixed close to the blast valve and between this and the Root's blower, this being opened to exhaust the surplus blast to the atmosphere as the cupola blast valve is regulated or closed (similar to the arrangement used on the Tropenas steel-converter blast-control valve.). This would automatically reduce the load on the blower, when it is required to limit the full volume of blast passing to the cupola. With the fan installation, blast-valve control is all that is required, and a relief valve is unnecessary, as regulating the valve automatically controls the amount of air that the fan can induce and deliver. In this connection, there is still a further point to be raised. At the end of the blow, when the iron and coke are being gradually melted and burnt out of the cupola, the resistance to the blast is also disappearing, which means that the blast valve during this period must be gradually closed, and be blown through at a low pressure, in place of the fan overloading itself in attempting to deliver this at a pressure relative to its speed.

In the Root's blower installation, as the volume of blast is constant under all conditions, the gradual removal of the resistance in the emptying of the cupola automatically takes the load off the blower and reduces the power consumed, the same volume of blast being delivered at a gradually diminishing pressure, and no special attention is necessary. Unless an automatic blast valve is fitted with the fan installation, the Root's blower has on this point a distinct advantage, as the regulation of the valve is left to the cupola man, who is apt to be careless unless he has a meter before him showing the increased power being consumed, or the driving belts begin to slip.

The only other indication of the increased blast blown through, is a large firework display at the top of the cupola, which is also an added nuisance, as the sparks are filling up the gutters and depositing on the surrounding roofs, or rapidly burning out the spark arrester and, what is *not* seen, the lining is rapidly wearing.

Calculation of Coke and Iron Charge.

The weight of metal charges to be used for any cupola is best calculated from the coke fusion charge, the coke "fusion" charge being the coke charged between the iron charges. As the best height for the coke charge is 6 in., the weight of iron charge can be calculated from the internal diameter of the cupola. Taking 4 cub. ft. of space per cwt. of coke, and 2 cwts. of fusion coke per ton of metal melted, as an average figure, we get:—

(1) Fusion coke in cwts. =

$$\frac{\text{Depth of coke in ins.}}{12} \times \frac{\text{Area of cross section of cupola in sq. ft.}}{\text{Cub. capacity of coke.}}$$

This is equivalent to,

$$\frac{6}{12} \quad \frac{\text{Area in sq. ft}}{4} \times \frac{\text{Area in sq. ft.}}{8}$$

(2) Taking 2 cwts. furnace coke per ton of metal melted as an average, we get—

$$\frac{\text{Area in sq. ft.}}{8} \times 10 = \text{weight of iron charge.}$$

Taking a cupola 4 ft. internal diameter for melting 7 tons per hour, we should get a fusion-coke charge of 1.57 cwts. and an iron charge of 15.7 cwts., coke being taken in this simple calculation at 4 cub. ft. per cwt.

Gauging the Coke Charge.

A better method than calculating the weight as above is shown in Fig. 6, which not only gives a more accurate method of ascertaining the weight of coke, but provides a measure for the furnaceman to work with, for while a man may judge the

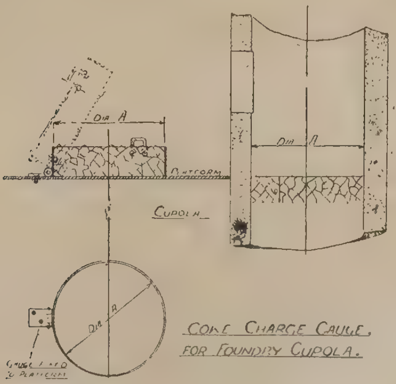


FIG. 6.—COKE CHARGING GAUGE.

iron charge fairly reasonably, the coke charged should not be subject to guesswork.

The apparatus comprises a strong sheet iron ring of the same internal diameter as the inside diameter of the cupola and 6 in. deep, which is conveniently placed in front of the cupola and hinged at one point so that it can be hinged down as illustrated, on to the platform, and filled with coke, then hinged up, while the coke is shovelled into the cupola, and until required for the next charge.

The iron charge would, of course, be calculated from a ring full of dry coke. Here we should like to add that only dry coke should be used, and coke should be stored under cover and kept dry. In emphasising this point, attention is called to the fact that in turning water into steam at atmosphere pressure, for every lb. so changed, there is lost, in addition to the sensible heat units, which is the difference between the temperature of the coke when charged and the escaping gases, approximately 750 British thermal units of latent heat in simply changing the water into steam at 212 deg. F. (100 deg. C.).

It might be argued that the coke will be dry long before it reaches the melting zone of the cupola, but this cannot alter the fact that the heat used in changing this water into steam at a high temperature cannot be used at the same time in heating up the iron charges moving down the cupola stack to the melting zone.

The Bed Coke.

The height of this above the top tuyeres is most important, and should not be estimated as so many barrows, or shovelfuls, but should be made up to a gauge, registering from the charging hole sill, and preferably made from, say, $\frac{7}{8}$-in. round iron with a foot turned out at right angles at the bottom, about 18 in. long for large cupolas, and not less than a foot for small cupolas, so that it will indicate when the bed is fairly level, the gauge to be marked for the charging hole level. The height of the bed coke above the top tuyeres will usually be about 2 ft. to 2 ft. 6 ins for cupolas of standard design, but this should be carefully ascertained by trial, a good guide for this being that the metal should under normal conditions appear at the spout in 10 to 12 minutes after putting on the blast.

As the weight of the bed coke is a very important item of cost, particularly when small blows are taken from a large cupola, this weight should be carefully noted when the correct height has been found, but a point often overlooked in stating the weight of the bed coke used is that this includes the first fusion coke charge, and this should be deducted after the gross weight has been found.

Charging Cupolas.

The charging of the cupola is a very important matter, and has considerable influence on the good working of the cupola. It is also a "work of art" in many places, where no weighing or gauging facilities for the materials to be charged, are provided. The melting of the iron in the vertical circular shaft, which is filled with alternate layers of fusion coke and iron, should come evenly into the melting zone, and the position of this melting zone must be maintained, and calls for careful feeding at the charging hole, and the mechanical device used should be one which will place the "charge" level in the cupola, as is done by hand charging. The usual mechanical charging to-day is done either by an inclined plane leaning against the shute of the cupola charging hole, with a bogie working up this incline, which tips its contents down the shute to the cupola, or buckets containing the charge are brought to the charging hole by means of a runway or crane, but the contents are again in this case tipped into the cupola.

Many people have special charging barrows, which are filled with the correct weight on the ground, taken to the platform level in a hoist, and duly tipped into the cupola. As far as the cupola is concerned, these methods are all alike, and the materials are shot into the cupola in an inclined path and cannot be said to be evenly placed in it. There are, of course, many cupolas doing good work, mechanically, but one cannot consider that the inclined plane charging arrangement is a proper or final solution of this problem. A far better method is to enlarge the cupola at the charging hole, so that the charging skep can be run right into the centre of the cupola, or arranged so that it can go in at one side and out at the other, as shown in Fig. 7. The charging skeps should be made the same internal diameter as the cupola and fitted with drop bottom door, so that the material can be dropped straight into the cupola.

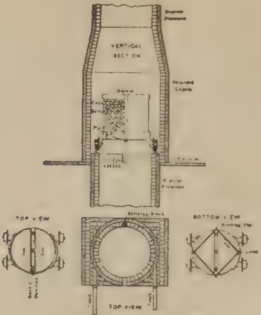


Fig 37 —Cupola bucket for mechanical charging.

Fig. 7.—Mechanical Charging.

The skeps in this case should be made of suitable depth, so that they also act as gauges for the correct weight. Two sizes should be used, one for the coke and the other for the iron, and each should contain one complete charge. This method would not only charge the cupola evenly as by hand, but would provide gauges to check the weight of the materials charged and would thus do away with guess work methods.

It is rather strange that the inclined plane method of charging should have been developed, as against the method suggested above. It may be a question of initial cost, which is well known has entered largely into the question of plant installation for the last six or seven years, or the difficulties of enlarging existing cupolas for the adoption of the method suggested, may have something to do with the question, but it is not a difficult or unpractical solution that is recommended here, and it is one which it is hoped will be more adopted in future.

Fig. 8 shows a Whiting cupola fitted with external receiver and connecting spout, with slag notch.

Many attempts have been made of recent years to increase the efficiency of the ordinary foundry cupola. The Schürmann cupola, which incorporates a hot-blast system, comprises the usual cupola body, two reheating chambers with the usual chequered brick chambers to the tuyeres, one chamber being connected to the tuyeres on one side of the cupola, and the other to the tuyeres on the opposite side. The chambers have a common chimney and a valve arrangement, so that either chamber can be alternatively coupled to the chimney, and simultaneously the blast from the blower is switched on to the chamber not connected to the chimney. The Schürmann principle was not to have a hot-blast cupola by making use of waste heat, but an attempt to burn the coke in a short incandescent path across the coke bed, and to prevent as far as possible, the partial and inefficient combustion of the coke in its passage down the cuopla, bringing the coke fresh as it were, into the melting zone, eliminating formation of CO and getting direct combustion to CO_2.

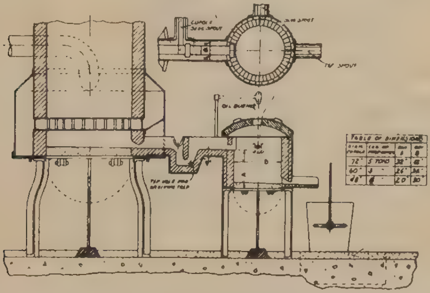


Diagram of Cupola and Fore-hearth

FIG. 8.—WHITING CUPOLA AND RECEIVER WITH SLAG NOTCH.

Ardelt Receiver.—This receiver is said to be particularly suitable for melting cast-iron charges with heavy steel additions. In this case the receiver hearth is on a level with the hearth of the cupola. The slag therefore floats on the metal in the cupola, and is trapped from entering the receiver. The slag formed is discharged through a slag notch fitted in the cupola.

A feature of the cupola shown in Fig. 9 is a removable well, which takes the place of the ordinary well in the standard form. The drop bottom in this case is a brick grid which is fitted between the cupola proper, and the receiver. The well receiver is mounted on wheels, the top arrangement giving a limited vertical movement, so that it can be set up hard in position under the drop bottom of furnace. The object of this arrangement is to cut out the bed coke below the tuyeres, introducing a receiver in direct association with the cupola. This receiver would have an open top for cleaning, and no making up of breast and the drop bottom being of a grid form, would enable the bed coke to burn through quickly.

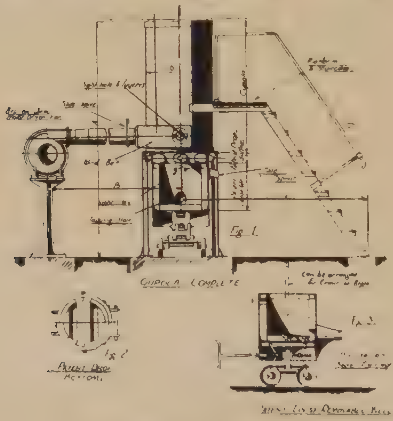


Fig. 9.—Removable Well Cupola.

DISCUSSION.

Mr. R. O. Patterson, further to Mr. Poole's remarks about coke, said that he was pleased to inform them that rather extensive tests of coke were being made at Blaydon under the auspices of the Northern Coke Committee and the British Cast Iron Research Association. It would be some weeks before the tests were finished, but at their conclusion Professor Briscoe had promised to give a Paper as soon as the results were tabulated. With regard to Mr. Poole's lecture, there was one point on which he totally disagreed with him, that was coke being charged layer by layer. Their cupolas were 4 ft. 6 in. dia. and as a general rule they blew with one pound pressure of air; incidentally he would not use a positive blower. They obtained 12 to 14 tons of metal per hour with a ratio of 14:1, at a temperature of anything from 1,380 to 1,450 deg. C. He agreed that it was a vital necessity to weigh the charges. They weighed all charges and did it by such a method that it was as easy for the men to be right as wrong. The material was put into a skip until the pointer came round and stopped. The size of furnace of which he was speaking used about 2,000 lbs. charge, but they had two shutes, one on either side, and they alternated from one side to the other.

Mr. Poole said that he was particularly interested in the figures that Mr. Patterson had given. With reference to charging in layers, he did not mean to suggest that one had to be so precise as Mr. Patterson inferred. Observing as he did so many cupolas, it was surprising the irregularity of charging which he had seen. He was quite in agreement with the double door method of charging, which may have had something to do with Mr. Patterson's success in the results he had obtained. Generally speaking, it might be said that not 60 per cent. of cupola plants had the charging door heights on the low side.

One or Two Rows of Tuyeres ?

Mr. C. Gresty said that on the whole he found himself in agreement with Mr. Poole. He differed, however, in his opinion as to the number of rows of tuyeres necessary; in his experience he had never yet been able to see why more than one row of tuyeres was needed if the cupola was properly designed. It was only adding unnecessary complications if there were two or more rows. Mr. Poole's remarks on the question of the vital effect of balancing the volume of air with the coke undoubtedly was the secret of successful cupola practice. A point on which he thought they would all be in agreement was the real difficulty of obtaining standard conditions for experimental work. Every cupola was a law unto itself, and one did not get identical results on them all. What appeared to be an important point was that towards the end of a blow a great advantage was obtained by reducing the blast going into the cupola. It saved the lining of the cupola and kept the composition of the metal the same. In some of the illustrations which Mr. Poole had shown as being typical of good layouts one thing was noticeable: the blast pipes were very short and had practically no straight lengths. If the volume of air was so important how was it to be measured if there was no straight run? Referring to the question of hot-blast cupolas, he (Mr. Gresty) was of the opinion that the length of cupola runs was usually so short—say, 3 or 4 hours—that the regenerating stoves would just be getting warmed up to the work when it was time to stop. Only in the case of furnaces which worked more or less continuously were the full advantages of hot blast obtained. Continuing, he asked Mr. Poole if he had had any experience with pulverised coal in the cupola. He himself had seen an experimental plant for the purpose on the Continent, but, unfortunately, had not been able to see it in operation. The reactivity of coke was an important matter and one which required further investigation, because although two cokes might have the same analysis and calorific value, yet, under similar conditions, they might burn at quite different rates.

Replying to Mr. Gresty, **Mr. Poole** said that he must admit that one row of tuyeres was all that was necessary if the conditions of blast were good, but that it was safer to have two rows. He agreed that with a hot-blast cupola a prolonged blow was best. He had had a little experience with pulverised fuel; the first time he had used it it had blown up. He had injected fuel oil with very interesting results, and he thought that the use of pulverised fuel and crude oil would be developed. The physical conditions of coke or coal had a profound influence on cupola work. Two cokes of the same analyses but with different physical conditions would burn differently. The difficulty was to standardise one condition against another.

Shape of Tuyeres.

Mr. Cooper, referring to the shape of tuyeres, said that Papers on cupolas were very misleading, because the shape had to be determined by the kind of iron melted. Some shapes of tuyeres would speed up the cupola if it was a question of pressure, but they would have a deleterious effect on the iron. They had found that some cupolas with tuyeres put in at regular intervals were producing remarkably good iron. It was necessary to keep the cupola clean, otherwise the iron would run down the side. As far as the jolting receiver was concerned, the reason why slag was found was because poor material was being used and the slag was shaken up. The Ardelt receiver left the larger portion of the iron in the cupola and there was a tendency for the temperature to drop. By burning coke to CO_2 the greatest possible advantage was obtained.

Mr. Poole replied that the shape and design of the tuyeres were extremely diverse, but it was most essential to control the volume of air and the pressure. With regard to the jolting receiver, he did not condemn the principle, for he thought there was a good deal in it.

Mr. V. Stobie (Chairman) said that he had noticed that the total carbon in the sample of Chinese iron Mr. Poole had shown them was 4.66 per cent. which was higher than it had been suggested could be taken up. With regard to the number of rows of tuyeres, if the same volume of air was coming out of each tuyere there would be no advantage. He agreed with Mr. Gresty that one row would be sufficient.

Mr. Poole said that regarding the T.C. in the sample of iron, he would not say that it was correct to 0.02 per cent. It was a saturated solution of carbon and iron and it had a particularly interesting micro-structure and was very easy to machine.

Mr. J. W. Frier proposed a hearty vote of thanks to Mr. Poole, which was seconded by Mr. Robson, and passed with acclamation, Mr. Poole replying briefly.

East Midlands Branch.

SOME EXPERIENCES IN PRACTICAL MOULDING.

By A. Sutcliffe, Associate Member.

It is proposed to outline a number of typical jobs, recently made, which might have been produced by either the dry sand or loam method. This matter is treated from a jobbing foundry point of view, and it is not claimed that these methods are in any way superior or even as good as might be possible if made in a foundry specially equipped for one class of work.

The best way to make some of the castings for quick delivery and good results has been borne in mind. It must be remembered that some of these castings are outside work, so they must be reasonably perfect or they will be returned as scrap. If made for internal consumption, some of the returns would be utilised, but the outside firms want exactly what they order, or will place their orders for castings elsewhere.

Second, delivery must be considered, or the work may be lost on account of failing to deliver orders to time. Sometimes a firm is not tied to a few shillings in the price of castings, if the delivery is good, as they can save the extra money by not having to wait at their works.

Third, when making castings for outside firms, the foundry is always up against competition, so it will pay the foreman, when an order comes in, to ascertain the cost, and if there is no profit on the job, to let it go elsewhere, or report it to his manager, as money can soon be lost in a jobbing shop by estimating jobs at too low a price.

There is also another thing to consider when orders are received and castings are required in a hurry: the hurried jobs are more liable to be defective because such items as the fact that two men cannot make a job, working two a day off one pattern, as quickly as one man can make one per day off the same pattern, are often overlooked. This is often neglected when estimating a price for a job. If it is a rush job and two men have to be put on the job to get the order through, often a matter of 3s. to 5s. in wages alone is lost, and then the profit is lowered to vanishing point.

It is also the foreman's duty to utilise inexpensive but not inferior materials. For instance, a large slotter, or one of the calender cheeks, to be dealt with later, had 30 chaplets 3 or 4 in. sq. top and bottom—that is, 60 in all. This would be no small item if there were four required off the pattern, and ordinary chaplets were used for all four simultaneously.

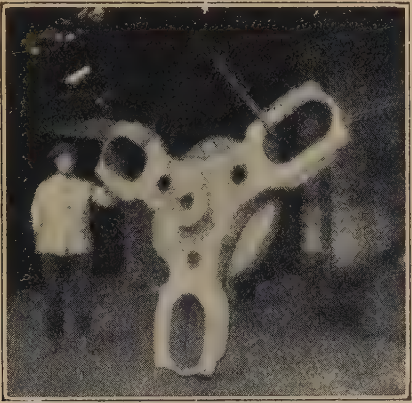


Fig. 1.

By fastening the cores according to the author's system there will be required thirty stumps, instead of wooden blocks; thirty studs made in cast-iron; thirty 3-in. sq. w.i. plates; these all being for the bottom half of the mould. The top will require thirty 3-in. or 4-in. sq. w.i. plates and thirty w.i. rods. The rods will answer for all four castings, if ordered sufficiently in advance and cut off close to the casting, when dressed, just allowing for the thickness of the four castings in the top part. All that is required after the first casting are fresh plates and studs. There are many castings in tool, engine and jobbing work where this system will apply, but avoiding steam and machinery castings, as the studs will cause the casting to leak in the steam variety and show up in machinery work similarly to any other stud.

Making a Casting in Cores with Top and Bottom in Sand.

When making the casting shown in Fig. 1 in cores with top and bottom in sand, a strickle should be used for both parts, the bottom to form the print and the top to get the depth of the casting, including the boss and the three arms.

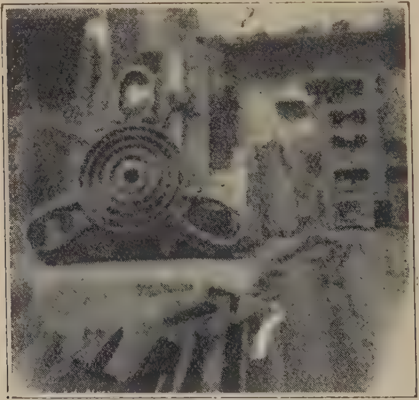


FIG. 2.

As the arms and boss are loose pieces, the boss fits over the spindle in the centre, by which means a quicker method is obtained for making the bed for the cores forming the bottom of the mould (Fig. 2). This centre spindle is also utilised for making the dummy for the top and getting the centre lines for the many things required. The three arms are set by the centre lines on the dummy, and this is how the top part of the casting is placed in the top box.

After the top box has been left off, the bottom should be dug out, and the spindle put in the dandy again in the centre of the box; the bottom strickle should then be fixed on. This is done to delineate the depth of the casting, which is now formed with cores, of which there are forty altogether (Fig. 3). When the cores are in position the vacant places should be rammed up to keep the cores in place. All the cores being in place and having worked to centre lines on the box edge, there need be no fear of the casting being out of shape.

The top box should then be tried on, and note should be taken that the vents of the three round cores that are attached to the three body cores are quite free to pass off, or there will be an explosion if the metal should get into any of these vents, resulting in the production of a bad casting.

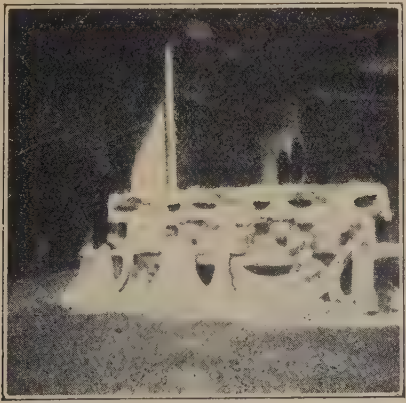


Fig. 3.

The runners and risers should be made up before the top box is put on, and it should be ascertained that the long narrow runner box comes to the moulding box edge, and then there will be better casting facilities provided for the ladle, so eliminating chances of accidents of burning from molten metal going anywhere instead of down the gits of the mould. The weight of the casting is 17 cwt., and the cores were made from

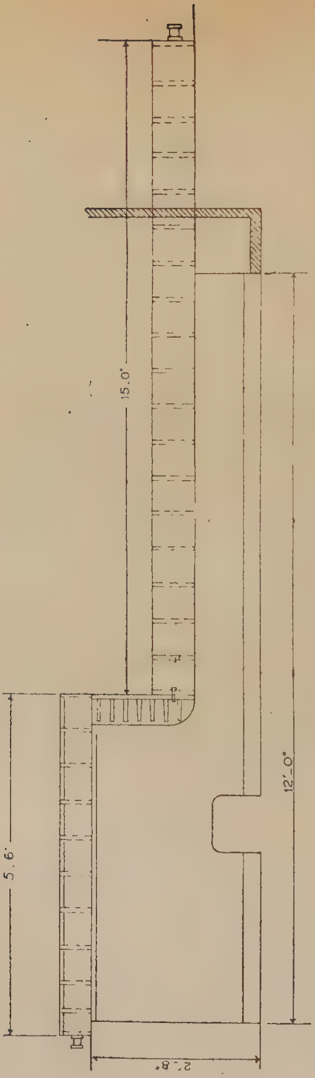


FIG. 4.

gum sand, except the three centre body cores, which were made by the use of oil-sand.

Step Moulding.

The author has carried out this kind of moulding in many shops, and he proposes to exemplify the system by describing the making of a lathe bed, such as shown in Fig. 4, from which it will be noted that there are two flat tops, which eliminate a joint of 18 in. deep. The pronged plate is bolted back to the box end as shown, but if there are no holes in the box, staples should be put in the plate, then a bar put through the

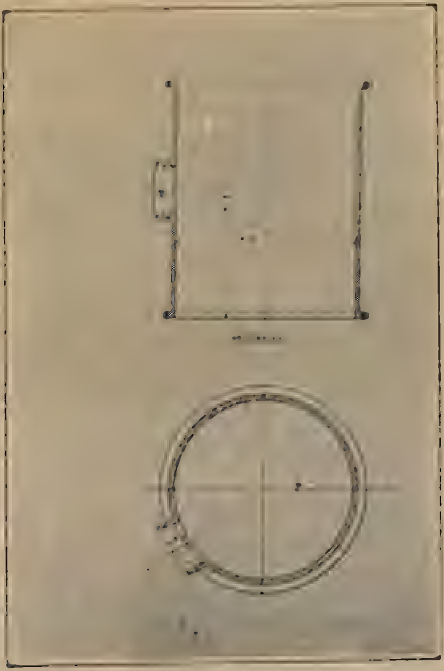


Fig. 5.

staples and behind the box bar, which permits of it being wedged up.

Considerable time can be saved on many jobs in a jobbing shop by using this method. It also creates an economy in lifting power as it eliminates much weight and packing for turning over the box for finishing.

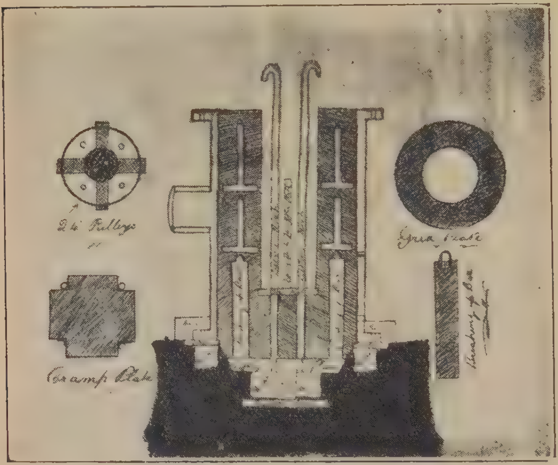


FIG. 6.

Large Branch Pipes.

Eight of these large branch pipes were made in sand and skin-dried, but one turned out to be a bad casting, so one more had to be made, which brought the total up to nine, Fig. 5.

It is not insisted that the job would not have been better made in loam, but it would not have been as cheap, but apart from this every firm does not empty a loam moulder, as there is not sufficient room in a small shop.

The sketch (Fig. 6) is quite clear. The casting is run from the top, and the branch core spiked back before the body core is put into place. The top flange is formed by segment, and the small square cores are put in to a templet.

The bottom flange is formed by a segment core all round, and the body of the casting is rammed up from the pulley rim about 3 ft. deep. This job was a valve tower in a reservoir, and the joints were not machined.

Kier Bottom in Skin-Dried Sand.

This casting is made from a strickle forming a saucer 15 in. deep and 9 ft. diameter, with a flange all round, the top can be made from this. There are five runners in the middle, all 1 in. dia. The four feet on the bottom are set by centre lines, and the boss over the spindle, the cores are put in the flange by templet. This casting is only $\frac{5}{8}$ in. metal.

It should be remembered that castings strain downwards as well as upwards, no matter what weight is on the top part. The mould is wet blacked with a Sheffield mineral blacking, and skin-dried. The blacking is put on with a swab, and the marks are then taken out by a brush. It is assumed that every founder knows that there is a cinder bed under all these kind of jobs, that a cross handle wire is used, and then a needle wire. The only sprigs on this job are a few under the gates. An order of twelve were made in loam and stove-dried.

Top and bottom plates were made with a spindle hole fixed in, so that after the first one was bricked up, the rest of the order, that is the top parts, only required sweeping up with a thin loam after being taken off the casting; the bottom required the feet and boss bedding in again to centre lines, then swept up in the ordinary way.

Prods were provided on the building plates so that the mould was cast above ground, and not rammed up. The strickles were the same, only a fresh one was required for the top. The tackle which would be required when making such a cast in loam would be:—Two plates top and bottom, 9 tons; one building ring, 1 ton; one grid, 7 cwt.; total, 10 tons 7 cwt.; whilst when working with sand only gaggers are needed, and these can be used again.

Holding Cores in Position.

Fig. 7 shows the way how to hold down cores and keep them in their place. The author has repeatedly used this method and found it to be the simplest of all.

Primarily, the taper stump should be knocked down in the solid sand, then the cast-iron stud of the size required for the thickness of metal with the 3-in. sq. plates on top is placed over it; this is all that is required to hold up the core, which should now be held down by the plate and rod. The size and diameter of the rod is determined by the thickness of metal. These rods can be put in the top box before it is tried on, and can be given a tap when the top box is on for the trial which will show just where to put the plates on the top side of the core. It must be noticed that the stalks are flat at both ends to enable them to be scotched up in the same way as an ordinary chaplet.

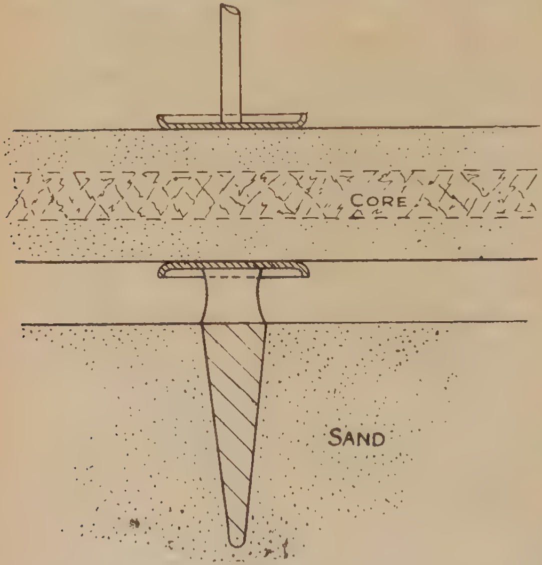


Fig. 7.

If the moulder does not use a tube to make a hole for the taper stump, three of these stumps under one core will carry a heavy weight. If he does it takes away the bearing of the weight. Actually the stump should be knocked down in solid sand.

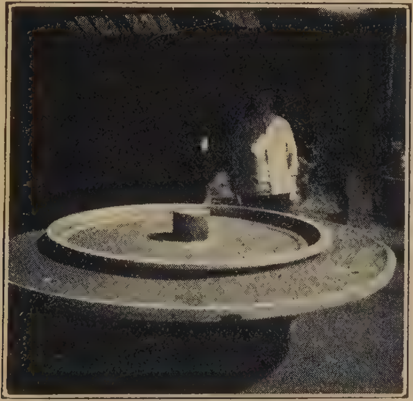


FIG. 8.

Wheel Moulding Machine Table.

The table shown in Fig. 8 is made from a strickle. The top can be made from a level bed with four centre lines to form a guide for four cores. This particular casting is a wheel moulding machine table for turbine cores, and carrying a dividing apparatus. It is used for dividing the plates in the turbine cores, but can also be used for wheel moulding. A strickle is used for forming the bottom part of the mould, and a core forms the master wheel, the teeth of which are cut ½ in. pitch. Should this part be bad the casting is scrapped, but if it is cast wheel-blank down there is a better chance of it being clean. The machining allowed on the top of the casting is only ¼ in. This job is run with three 1¼-in. gates in the boss, and two 1-in. gates on the wheel blank, wet blacked and skin-dried. The weight of the casting is 32 cwt., and the diameter is 8 ft.

Internal Wheel.

The internal wheel for the above is made on Jackson & Bros. wheel moulding machine. It is 6 ft. diameter, and is made in male and female box, *i.e.*, top and bottom, and can be moulded at the same time by two men working apart, which saves time on an urgent job. The outside diameter and plate of the wheel in question is formed by strickling. The cross and boss fit on the spindle and are bedded in below the plate of the wheel, and the four cores are put in place by centre lines. The teeth from an internal tooth block with one tooth; if the wheel block had any more teeth it would not be a true wheel. As shown in Fig. 9, the mould is on the machine table with the machine arm slung back, but is cast on the floor in green sand. There are two gates on the boss, and two on the rim. The stoppers are lifted from the rim first. This was a very good casting and was also a breakdown job.

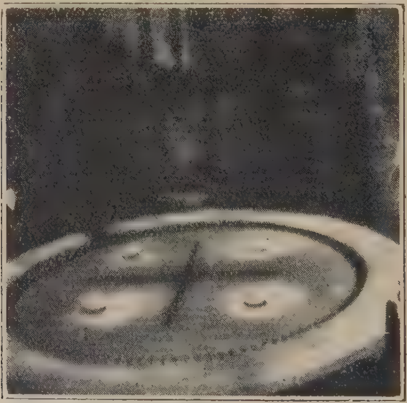


FIG. 9.

Calender Cheek.

In the early part of this Paper reference was made to this casting, which requires 30 chaplets top and bottom (Fig. 10). The casting weighs 4 tons and the metal is run in the foot with 3 in. sq. down gate, and an inlet 3 in. broad, $\frac{7}{8}$ in. thick and 14 in. long. There is also a small in-gate at the top of the mould to stop the metal from spinning, as this will drag in the top, if it is not rammed hard and well gaggered. On account of this casting being 18 ft. long and 10 ft. wide at the foot it had to be covered with two top-parts. The joints between the top boxes of all four castings could hardly be seen when dressed.

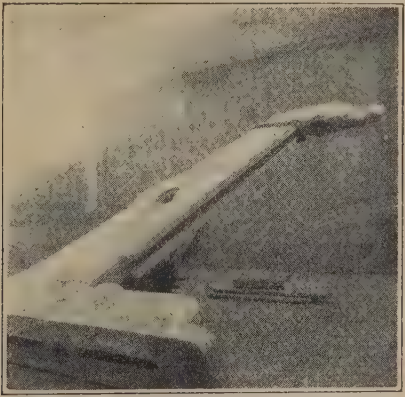


FIG. 10.

The box parts were provided with lugs and flanges, so an overlap grid was made for each box; by this a close sand joint was obtained in the centre of the two boxes. In moulding the bottom a cinder bed is put in, but no hay should be used on top of this, as it serves no useful purpose. The sand should be thrown in the hole and rammed up (Fig. 11).

The pattern should be bedded on black sand, then an inch of facing sand should be laid all over, and the pattern bedded down again on this. This should now be a solid bed. Now ram up the pattern and make the joint in the ordinary way ready for the top parts—one at a time, as a joint on the slant will have to be made on the first one. This joint will govern the putting on of these top parts when finished. Provided the weighting or bolting down is controlled, the result should be good.

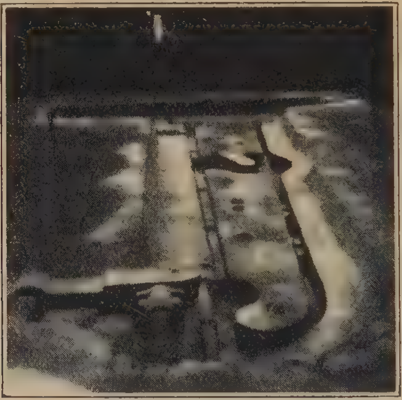


FIG. 11.

The group of castings in Fig. 12 comprise two machine-made bevel wheels, one blank wheel, and one clutch body. These are all green sand jobs. The large wheel is split with parting plates; at one time this gave trouble in getting parting plates to split cleanly, and the firm concerned tried everything in the way of daubing these plates, such as tar, asbestos, red lead and even goat's milk. However, there are still many pulleys and wheels that require splitting, but trouble is never experienced, as the author merely casts the plates, daubs them with thin oil, sprinkles parting sand on them, and dries one side at a time in the stove or over the fire. The wheel blank is also split. The clutch body has sometimes been made in loam, and sometimes in the floor by skin-drying from a strickled mould, and the small ones from a full pattern in green sand. Poor castings come about by turning them on the side to bare. The result is a crooked boss. Another failure was due to cracking on the plate; whilst a third, which was cast "boss up," was strained on the body and the metal ran out. Now all these mistakes mean

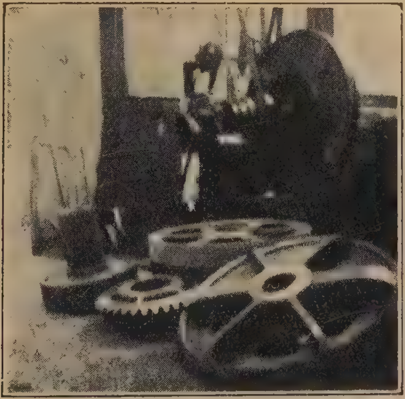


Fig. 12.

starting all over again, and none of them is the result of bad moulding. It is just through lack of knowledge that they occur.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

LIST OF MEMBERS.

May, 1929.

B.—Birmingham and West Midlands Branch.
E.M.—East Midlands Branch.
Lncs.—Lancashire Branch.
L.—London Branch.
M.—Middlesbrough Branch.
N.—Newcastle-on-Tyne Branch.
S.—Sheffield Branch.
Sc.—Scottish Branch
W. & M.—Wales and Monmouth Branch.
W.R. of Y.—West Riding of Yorkshire Branch.

Gen.—General or unattached to a Branch.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1926.	Ackroyd. A. H., White Cottage, Park Road, Timperley, Cheshire.
E.M.	1908.	Aiton, J. A. (Aiton & Company), Derby.
S.	1924.	Alder, A. J., 106, Sincil Bank, Lincoln.
N.	1924.	Allan, F., 7, Dene Street, Sunderland.
S.	1928.	Allan, J. B., 10, Whiteley Wood Road, Sheffield.
S.	1918.	Allan, J. M., "Broomcroft," Parkhead, Sheffield.
B.	1906.	Allbut, J. E. H., Woodcote, Bourne Street, Dudley, Staffs.
W. & M.	1928.	Allday, G. W., Llanerst, Somerton Road, Newport.
S.	1906.	Allen & Company, Edgar (Subscribing Firm), Imperial Steel Works, Sheffield.
B.	1928.	Allen, T. F., The Drive, Gravelly Hill, Birmingham.
E.M.	1924.	Allin. G. E., Ashleigh Grove, Etwall, near Derby.
Sc.	1927.	Anderson, G. L., Esq., 25, Cluny Drive, Edinburgh.

B'nch.	Year of Election.	MEMBERS.
Sc.	1920.	Andrew, J. H., D.Sc., Royal Technical College, Glasgow.
Lncs.	1919.	Andrew, J. W., 964, Oldham Road, Thornham, Royton, Oldham.
N.	1925.	Appleyard, K. C., Birtley Springs House, Birtley, Co. Durham.
N.	1921.	Armstrong-Whitworth & Co., Ltd., Sir W. G. (Subscribing Firm), Close Works, Gateshead-on-Tyne.
M.	1926.	Armstrong, H., 20, Shaftesbury Street, Stockton-on-Tees.
Sc.	1920.	Arnott, J., 114, Broomhill Road, Newlands, Glasgow.
Lncs.	1924.	Arstall, J., "Kenmarlean," Back, Bowe, Hyde, Cheshire.
M.	1927.	Ashmore, Benson Pease & Co., Ltd., (Subscribing Firm), Parkfield Works, Stockton-on-Tees.
B.	1924.	Aston, A., "Newlyn," Birches Barn Road, Wolverhampton.
L.	1911.	Aston, W. H., 46, Eagle Wharf Road, London, N.
B.	1921.	Athey J. W. (Major), Fordath Eng. Co., Ltd., Hamblet Works, West Bromwich.
Lncs.	1928.	Bacon, J. R., Bulay Road, Springdale, Huddersfield.
L.	1925.	Bagshawe, A. W. G., DunstableWorks, Dunstable.
Sc.	1929.	Baird, H. A., Loaningdale, Biggar, Scotland.
B.	1920.	Ball, F. A., c/o Ball Bros., Stratford-on-Avon.
B.	1929.	Bamford, W. H., 44, Norfolk Road, Erdington, Birmingham.
M.	1926.	Barbour, A. R., Bon Lea House, Thornaby-on-Tees.
L.	1923.	Bargellesi, G., Foundry Consulting Engineer, via Tantardini 13, Milano 123, Italy.
L.	1911.	Bartlett, A. R., 1, Lower Park Road, Belvedere, Kent.

B'nch.	Year of Election.	MEMBERS.
L.	1923.	Bartram, J., 369, Grove Green Road, Leytonstone, E.1.
M.	1926.	Bashford, T. E., "Hillingdon," South Road, Norton-on-Tees.
E.M.	1921.	Bates, W. R., United Steel Companies, Limited, Irthlingboro' Iron Works, Wellingboro'.
Lncs.	1929.	Baxendale, Rd., 8, Windsor Road, Chorley.
Gen.	1926.	Baxter, J. P., Morro Velho, E.F.C., Raposos Minas, Brazil, S. America.
W. & M.	1922.	Bayley, J. P., "Ty-gwyn," 4, Westfield Road, Clytha Park, Newport, Mon.
Lncs.	1928.	Bayne, James, Hill Top, Mill Lane, Rainhill, Lancs.
L.	1920.	Beech, A. S., 13-15, Wilson Street, London, E.C.2.
Sc.	1917.	Bell, J., 60, St. Enoch Square, Glasgow.
Sc.	1910.	Bell, W., 14, North St., Maryport, Cumberland.
Gen.	1922.	Bell, Wm. Dixon, 72, Walpole Road, Itchen, Southampton.
L.	1926.	Belling, C. R., 10, Glebe Avenue, Enfield, Middlesex.
Lncs.	1925.	Bennett, A., 57, Lodge Lane, Newton, Hyde.
L.	1926.	Bennett, F. H., "Holyrood," 12, Kilmarton Road, Goodmayes, Essex.
W. & M.	1929.	Bennett, J., Ebley, near Stroud, Gloucestershire.
S.	1920.	Benson, E. C., 303, Fulwood Road, Sheffield.
W.R. of Y.	1922.	Bentley, J. N., The York Engineering Co., Plantation House, Hull Road, York.
Lncs.	1922.	Bentley, L. A., Wood End, Bromley Cross, Bolton.
Lncs.	1925.	Best, J. (junr.), "Netherleigh," Manchester Road, Over Hulton, Bolton.

B'nch.	Year of Election.	MEMBERS.
B.	1924.	Bethell, R. P., 51, Sutton Road, Walsall, Staffs.
B.	1925.	Bettinson, C. L.. New Bond Street Ironworks,Bordesley,Birmingham.
E.M.	1915.	Bigg, C. W., Someries, Darley Lane, Allestree, nr. Derby.
S.	1918.	Biggin, Frank, Rye Lodge, Ashland Road, Sheffield.
L.	1929.	Birchall, J. S., c/o 7, Bramhall Street, Rochdale.
N.	1929.	Bird, Major T. G., 5, Manor Terrace, Tynemouth, Northumberland.
N.	1921.	Birtley Iron Company (Subscribing Firm), Birtley, Co. Durham.
W. & M.	1927.	Biss, H. H., "Westcroft," Fields Park Avenue, Newport, Mon.
B.	1922.	Blackburn, W. A., "Wynsill," Lichfield Road, Rushall, Staffs.
L.	1927.	Blackwell, F. O., 29, Westbourne Road, Luton, Beds.
Gen.	1919.	Blair, A., 7, Derryvolgie Avenue, Belfast.
W.R. of Y.	1926.	Blair, J. W., 32, Fifth Avenue, Heworth, York.
W. & M.	1928.	Bloodworth, C. J., 16, Newerne Street, Lydney Junction, Gloucestershire.
L.	1928.	Bone, K. T. J., "Braemar," Hightown Road, Luton.
B.	1912.	Boote, E. M., 11, Lydgate Road, Coventry.
L.	1912.	Booth, C. C., Mildmay Works, Burnham-on-Crouch.
E.M.	1919.	Booth, J. H., Fletton Spring House, Peterborough.
L.	1920.	Booth, P. M., 615, Finchley Road, N.W.3.
Gen.	1929.	Branson, S. A., Zakl. Mech. Ursus, p. Wlochy k/Warszawy, Poland.
N.	1922.	Brailsford, A., 18, Elswick Row, Newcastle-on-Tyne.
L.	1926.	Brendle, T. F., Hospital Road, Insein, Lower Burma.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1914.	Bridge, W., 199, Drake Street, Rochdale, Lancs.
B.	1928.	Briggs, E. R., The Mount, Lawford Road, Rugby.
S.	1922.	Brightside Foundry and Engineering Co., Ltd. (Subscribing Firm), Newhall Ironworks, Sheffield.
M.	1926.	British Chilled Roll & Engineering Co., Ltd. (Subscribing Firm), Empire Works, Haverton Hill, Middlesbrough.
Lncs.	1919.	Broad, W., 230, Dumers Lane, Radcliffe, Lancs.
S.	1922.	Brown, E. J., 11, Newlyn Place, Woodseats, Sheffield.
W.R. of Y.	1917.	Brown, P., Park Works, Lockwood, Huddersfield.
S.	1919.	Brown, P. B., Carsick Grange, Sheffield
Lncs.	1924.	Bruce, A., "Rose Bank," Swanpool Lane, Aughton, Ormskirk, Lancs.
B.	1926.	Buchanan, G., Niagara Foundry Co., Ltd., Bradley, near Bilston.
S.	1928.	Buckley, G. R., Churchfield House, Eckington, near Sheffield.
Gen.	1922.	Bull, R. A., 541, Diversey Parkway, Chicago, Ill., U.S.A.
L.	1924.	Bullers, W. J., Waterloo Foundry, Willow Walk, Bermondsey, S.E.1.
B.	1929.	Bullock, F., 67, Dudley Road, Tipton, Staffs.
Lncs.	1924.	Bullock, T. W., "Shirley," Warrington Road, Rainhill, Liverpool.
E.M.	1910.	Bunting, H., 82, Otter Street, Derby.
E.M.	1905.	Burder, K. M., "Clavering," Ashby Road, Loughboro'.
L.	1927.	Bureau of Information on Nickel, Ltd., 2, Metal Exchange Buildings, Leadenhall Avenue, E.C. (Subscribing Firm).
B.	1922.	Burn, A. J. H., 34, Old Road, Llanelly, S. Wales.
W.R. of Y.	1922.	Burnley, H., Water Lane Foundry, Bradford, Yorks.

B'nch.	Year of Election.	MEMBERS.
S.	1923.	Butler, J., 63, Deepdale Road, Rotherham.
Lncs.	1926.	Button, L. J., 294, Nantwich Road, Crewe.
M.	1909.	Caddick, A. J., "Eastbrook," 34, The Avenue, Middlesbrough.
Lncs.	1926.	Cadman, E., 69, Manchester Road, Fairfield, Manchester.
L.	1927.	Calder, N. G., 68, Conyers Road, Streatham, London, S.W.16.
Sc.	1917.	Cameron, J. (Cameron & Roberton, Limited), Kirkintilloch.
Sc.	1919.	Cameron, T. P. (Cameron & Roberton, Ltd.), Kirkintilloch.
S.	1922.	Cammell Laird & Co., Ltd., (Subscribing Firm), Cyclops Steel and Iron Works, Sheffield.
Sc.	1927.	Campbell, H. D., Shaw (Glasgow) Ltd., Maryhill Iron Works, Glasgow.
Sc.	1911.	Campion, A. (Honorary Life), 3, Strathview Gardens, Bearsden, Glasgow.
S.	1923.	Cantrill, W. H., 249, Chatsworth Road, Chesterfield.
N.	1912.	Carmichael, J. D. (Life), Sydenham Terrace, South Shields.
N.	1912.	Carmichael, J. D., Jun., O.B.E. (Life), "Redlea," Grasmere Gardens, Harton, South Shields.
L.	1919.	Carpenter, H. C. H., Prof. (Hon.), 30, Murray Road, Wimbledon, S.W.19.
L.	1929.	Carr, A., 240a, Bennetts Castle Lane, Chadwell Heath, Essex.
L.	1927.	Cassidy, G. L., c/o The Morgan Crucible Co., Battersea Works, Church Road, Battersea.
S.	1921.	Castle, Geo. Cyril, Beecroft and Partners, Ltd., St. Peter's Square, Sheffield.
S.	1927.	Cawood, G. R., & Co., Ltd., 1, Cavendish Road, Leeds. (Subscribing Firm.)

B'nch.	Year of Election.	MEMBERS.
Lncs.	1905.	Chadwick, J. (Life), School Hill Iron Works, 12, Nuttall Terrace, Bolton.
Lncs.	1919.	Chadwick, J. N. (Life member), School Hill Iron Works, 12, Nuttall Terrace, Bolton.
L.	1919.	Cheesewright, W. F. (Col.), D.S.O., "Padgham," Dallington, Sussex.
L.	1925.	Chell, E., A.M.I.Mech.E., 68, Ferndene Road, London, S.E.24.
L.	1928.	Christopher, H., "Almira," Hillfield Road, Hemel Hempstead, Herts.
Gen.	1923.	Clamer, G. H., 129, So. Berkeley Square, Atlantic City, N.Y.
L.	1925.	Clapp, H. B., 25A, Broad Bridge Street, Peterborough, Northamptonshire.
L.	1928.	Clark, F. H., 84, Oxford Road, Hoe Street, Walthamstow, Essex.
S.	1922.	Clark, G., 61, Westbourne Road, Sheffield.
L.	1928.	Clark, H. A., 22, Eastfield Road, Hoe Street, Walthamstow, Essex.
L.	1915.	Clark, H. S., 17, Filey Avenue, Stoke Newington, London, N.16.
M.	1926.	Clark, W. H., 90, Marton Burn Road, Middlesbrough.
E.M.	1919.	Clarke, A. S., "Lyndesfarn," Leicester Road, Loughborough.
B.	1926.	Clarke, W. H., 16, Holly Road, Edgbaston, Birmingham.
L.	1928.	Clayton, G. C., 91a, Northgate Street, Bury St. Edmunds.
L.	1917.	Cleaver, C., 10, Ringcroft Street, Holloway, N.1.
W. & M.	1917.	Clement, W. E., Morfa Foundry, New Dock, Llanelly.
L.	1913.	Coan, R., Aluminium Foundry, 219, Goswell Road, E.C.1.
Sc.	1917.	Cockburn, N., 48, Murrayfield Gardens, Edinburgh.
L.	1925.	Cockram, G. F., 54, Murray Road, Ipswich.

B'nch.	Year of Election.	MEMBERS.
L.	1926.	Coggon, H. F., 10, Rhodesia Avenue, Halifax.
L.	1927.	Coleman, C. W., 1, Lancaster Place, Waterloo Bridge, Strand, London, W.C.2.
N.	1926.	Colls, F. C., Clarendon House, Clayton Street, Newcastle.
L.	1922.	Coll, J., Fundicion de San Antonio S.A., Seville, Spain.
B.	1927.	Collier, J. V., 45, Sheep Street, Northampton.
N.	1912.	Collin, J. J., 55, Cleveland Road, Sunderland.
N.	1916.	Collin, T. S., 4, Argyle Square, Sunderland.
N.	1922.	Consett Iron Co., Ltd. (Subscribing Firm), Consett, Co. Durham.
B.	1904.	Cook, F. J., 31, Poplar Avenue, Edgbaston, Birmingham.
Lncs.	1911.	Cooper, C. D., Dolphin Foundry, Chapel Street, Ancoats, Manchester.
N.	1921.	Cooper, J. H., 69, Stanhope Road, Darlington.
L.	1925.	Cooper, M. J., 5, Mildmay Road, Burnham-on-Crouch, Essex.
W. & M.	1928.	Corbin, F. D., 181, Tyrfran, Llanelly.
L.	1928.	Corrie, J. B., Co., Ltd., 15, Victoria Street, Westminster, S.W.1. (Subscribing Firm.)
L.	1926.	Coupe, J., 9, Delhi Road, Edmonton, London, N.9.
Sc.	1928.	Cowan, H., Foundry Technical Institute, Meeks Road, Falkirk.
Lncs.	1924.	Cowlishaw, S. D., 7, Temple Street, Basford, Stoke-on-Trent.
L.	1925.	Cowper, L., "Dellwood," Leichhardt Street, Gleve Point, Sydney, N.S.W., Australia.
E.M.	1914.	Cox, J. E. (The Rutland Foundry Company, Limited), Ilkeston.

B'nch.	Year of Election.	MEMBERS.
L.	1927.	Cox, S., 39, Gerrard Street, Shaftesbury Avenue, London, W.1.
B.	1922.	Cramb, F. M., 5, Triangle Villas, Oldfield Park, Bath.
L.	1910.	Cree, F. J., Fair View, Huntley Grove, Peterborough.
L.	1911.	Creighton, T. R., The Foundry, Stepney Causeway, E.
Lncs.	1927.	Crewdson, Capt. R. B., 16, Norfolk Crescent, Hyde Park, London, W.
W.R. of Y.	1922.	Croft, Frank, Crofts, Ltd., Bradford.
M.	1926.	Crosthwaite, C., Thornaby Hall, Thornaby-on-Tees.
M.	1926.	Crosthwaite, Ltd., R. W. (Subscribing Firm), Union Foundry, Thornaby-on-Tees.
Sc.	1929.	Cumming, W., & Co., Ltd., Kelvinvale Mills, Maryhill, Glasgow. (Subscribing Firm.)
L.	1923.	Curtis, A. L., 39, London Road, Chatteris, Cambs.
W. & M.	1929.	Curtis, J., Church Road, Charlestown, St. Austell, Cornwall.
Lncs.	1925.	Daniels, W., 74, Smethurst Lane, Bolton.
N.	1925.	Darlington Railway Plant and Foundry Co., Ltd. (Subscribing Firm), Bank Top, Darlington.
Gen.	1926.	Darnis, I. S., Ingeniero Industrial, Altos Hornos de Vizcaya, Apartado 116, Bilbao, Spain.
Lncs.	1926.	Davenport, J., Myrtle Bank, Grimsargh, Preston.
W. & M.	1928.	Davies, John, 12, Windsor Road, Treforest, S. Wales.
Gen.	1919.	Davies, P. N., 29, Brunswick Road, Brunswick, Melbourne, Victoria, Australia.
L.	1927.	Davis, J. K. (Davis Gas Stove Co.), Luton, Beds.

B'nch	Year of Election.	MEMBERS.
B.	1928.	Dawkins, W. A., Lansdowne Avenue, Codsall, Wolverhampton.
Lncs.	1924.	Dawson, S. E., 8, Lynton Park Road, Cheadle, Hulme, Cheshire.
Lncs.	1924.	Deakin, F., 14, Belfield Road, Reddish, Stockport.
B.	1918.	Deakin, W., "Thornlea," Sandy Hill, Shirley, Birmingham.
Gen.	1925.	Dean, J. P., 9, Stalmine Road, Walton, Liverpool.
Sc.	1927.	Deas, John, c/o John Deas & Co., Ironfounders, Market Street, Glasgow, E.
M.	1919.	Deas, P., 4, Blenheim Terrace, Coatham, Redcar.
L.	1925.	Delport, V. (Capt.), 2–3, Caxton House, S.W.1.
B.	1924.	Denham, H., "Birchwood," Walsall Road, Aldridge, Staffs.
S.	1917.	Desch, C. H., D.Sc., Ph.D., F.R.S., F.I.C., The University, Sheffield.
L.	1927.	Deschamps, J., "The Coppice," Garth Road, Letchworth.
L.	1926.	Dews, H. C. (Dewrance & Co.), 165, Great Dover Street, S.E.1.
B.	1921.	Dicken, Charles, H., "New Vale," Station Road, Balsall Common, Coventry.
S.	1924.	Didden, Capt. F. G. J., M.I.Mech.E., Broad Elms Lane, Ecclesall, Sheffield.
B.	1928.	Dobson, F. E., "Oaksey," Lichfield Road, Four Oaks, Warwickshire.
L.	1914.	Dobson, W. E., "Newlyn," Grand Drive, Raynes Park, S.W.
B.	1926.	Dodd, W., 68, Allport Road, Cannock, Staffs.
Lncs.	1928.	Dodds, J. W., Kensington House, Ashfield Road, Chorley, Lancs.
Lncs.	1928.	Doodson, T. E., "Glenroyd," Hesketh Drive, Southport.
Lncs.	1918.	Doughty, E., 54, St. Mary's Road, Moston, Manchester.

B'nch	Year of Election.	MEMBERS.
Sc.	1911.	Doulton, B. (Life), Elm Dene, 26, St. Mark's Hill, Surbiton, Surrey.
M.	1927.	Downing, A. G., 2, Oxford Street, Stockton-on-Tees.
Lncs.	1927.	Drake, T., South Bank, Stockport Road, Timperley, Cheshire.
E.M.	1929.	Driver, J. F., M.I.Mech.E., 65, Middleton Place, Loughborough.
S.	1921.	Duckenfield, W., 47, Dunkeld Road, Ecclesall, Sheffield.
L.	1928.	Duguid, Islor, 119, High Holborn, W.C.1.
L.	1925.	Durnan, F., Camelon Iron Works, Falkirk.
Lncs.	1926.	Durrans, J., The Croft, Penistone.
S.	1921.	Edginton, G., Silverdale, St. Margaret's Drive, Chesterfield.
B.	1922.	Edwards, A., "Dunbar," Old Bath Road, Cheltenham.
M.	1927.	Edwards, A., "Wayside," Nunthorpe, Middlesbrough.
N.	1921.	Eldred, E. J., 8, Ford Street, Gateshead-on-Tyne.
L.	1904.	Ellis, J., 51, Riddings Lane, Wednesbury.
S.	1918.	Elliss, J. A., 217, Middlewood Road, Sheffield.
S.	1913.	Else, L. H., 79, Osborne Road, Sheffield.
Sc.	1925.	English, J., c/o Miss Granger, 9, Prospect Street, Camelon, Falkirk.
L.		Ephraim, V. Rex, 21, Cromwell Road, S.W.7.
L.	1919.	Estep, H. Cole, The Penton Publishing Co., Penton Building, Cleveland, Ohio, U.S.A.
L.	1926.	Evans, S., 9, Bush Lane, Cannon Street, E.C.4.
E.M.	1918.	Evans, W. T., Mount Pleasant. Sunny Hill, Normanton, Derby.
S.	1920.	Fairholme, F. C., Norfolk Works, Sheffield.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1926.	Farrington Steel Foundry of Leyland Motors, Ltd. (Subscribing Firm), Leyland, Lancs.
L.	1908.	Faulkner, V. C., 49, Wellington Street, Strand, London, W.C.2.
S.	1910.	Feasey, J., 192, West Parade, Lincoln.
B.	1914.	Field, H., "Glenora," Richmond Avenue, Wolverhampton.
B.	1904.	Finch, F. W. (Honorary), 52, Denmark Road, Gloucester.
S.	1914.	Firth, A., 50, Clarendon Road, Fulwood, Sheffield.
S.	1914.	Firth, F. W., "Storth Oaks," Ranmoor, Sheffield.
M.	1926.	Fisher, F. E., 2, Albert Terrace, Haverton Hill, Middlesbrough.
S.	1929.	Fisher, F. M., Devonshire Avenue, Beeston, Notts.
Gen.	1907.	Flagg, S. G. (Honorary), 1407, Morris Buildings, Philadelphia, Penn., U.S.A.
B.	1923.	Flavel, P., Bushbury Lodge, Leamington.
B.	1922.	Fletcher, J. E., M.I.Mech.E. 8, St. James Road, Dudley, Staffs.
Lncs.	1923.	Flower, E., 7, Marlborough Street, Higher Openshaw, Manchester.
W. & M.	1907.	Fontaine, C., Dock Foundry, Newport, Mon.
Sc.	1917.	Forbes, J. T., 176, West George Street, Glasgow.
B.	1926.	Fordath Engineering Co., Ltd. (Subscribing Firm), Hamblet Works, West Bromwich.
W.R. of Y.	1922.	Forrest, H., 43, Beaumont Road, Manningham, Bradford.
N.	1919.	Fortune, T. C., 76, Falmouth Road, Heaton, Newcastle-on-Tyne.
B.	1919.	Fosseprez, G., 3, Rue du Grand Jour, Mons, Belgium.

B'nch.	Year of Election.	MEMBERS.
—	1926.	Fox, F. S., 5532, Webb Avenue, Detroit, Michigan, U.S.A.
W.R. of Y.	1925.	Frame, J. Y., 19, Sherburn Street, Hull.
L.	1926.	France, G. E., "Clay Bank," Pellon, Halifax.
Sc.	1920.	Fraser, A. R., High Craigton, near Milngavie.
N.	1914.	Frier, J. W., 5, Northumberland Villas, Wallsend-on-Tyne.
L.	1919.	Furmston, A. C., Hope Cottage, 211, Neville Road, Letchworth.
W. & M.	1924.	Galletly, J. P., Ben Clench, Pencisely Road, Cardiff.
B.	1928.	Gameson, T. H., 47, Somerset Road, Handsworth Wood, Birmingham.
Sc.	1919.	Gardner, J. A., 24, South Hamilton Street, Kilmarnock.
L.	1922.	Gardom, J. W., 39, St. Peters Road, Dunstable, Beds.
B.	1928.	Garman, B. A., Yew Tree House, Great Barr, Birmingham.
Lncs.	1922.	Garner & Sons, Limited (Subscribing Firm), Victoria Street, Openshaw, Manchester.
Lncs.	1919.	Gartside, F., 18, George Street, Chadderton, Lancs.
Gen.	1927.	Geilenkirchen, T., Dusseldorf, Faunastr 37, Germany.
L.	1926.	George, H., "Southdene," High Street, Dunstable.
Sc.	1929.	Gibb, J., Blairmore, Newmains, Scotland.
L.	1922.	Gibbs, A. F., 55, Gordon Road, Wanstead, Essex.
S.	1925.	Gill, C. S., 60, Riverdale Road, Sheffield.
Sc.	1920.	Gillespie, P., "Glenora," Falkirk Road, Bonnybridge.
Sc.	1925.	Gillespie, W. J. S., Ure Allan Park, Bonnybridge, Stirlingshire.
E.M.	1915.	Gimson, H., "Rhoscolyn," Toller Road, Leicester.

B'nch	Year of Election.	MEMBERS.
E.M.	1906.	Gimson, S. A., 20, Glebe Street, Leicester.
E.M.	1928.	Glover, W., 69, Cardigan Street, Derby.
S.	1929.	Goddard, A. V., "Brentwood," King Egbert Road, Totley, Sheffield.
S.	1905.	Goodwin, J. T., M.B.E., M.I.Mech.E. Red House, Old Whittington, Chesterfield.
M.	1926.	Gore, G. E., "Rosedene," Austin Avenue, Stockton-on-Tees.
W. & M.	1917.	Gould, P. L., Vulcan Foundry, East Moors, Cardiff.
Sc.	1921.	Graham, J., 68, Sherbrooke Avenue, Maxwell Park, Glasgow.
L.	1926.	Grange, R., 89, Constantine Road, Hampstead, N.W.3.
Lncs.	1920.	Grant, G. C. (Sir W. G. Armstrong, Whitworth & Company, Limited), Ashton Road, Openshaw, Manchester.
N.	1921.	Gray, C. R., 14, Latimer Street, Tynemouth.
L.	1926.	Gray, T. H., 119, High Holborn, W.C.1.
L.	1927.	Greaves, Dr. R. H., 6, Clifton Terrace, Southend-on-Sea.
B.	1925.	Greensill, G. B., "Lynn," Jockey Road, Sutton Coldfield.
N.	1912.	Greensitt, R. H., 24, Stuart Terrace, Felling-on-Tyne.
E.M.	1920.	Greenwood, R., The International Combustion Engineering Co., Derby.
N.	1917.	Gresty, C., 101, Queen's Road, Monkseaton.
W. & M.	1906.	Griffiths, H., 70, Partridge Road, Cardiff.
W. & M.	1927.	Griffin, E. H., 196, Henleage Road, Henleage, Bristol.
Lncs.	1927.	Grundy, H., 20, Thoresway Road, Longsight, Manchester.

B'nch.	Year of Election.	MEMBERS.
W. & M.	1928.	Gundry, P., Polbathic, Cornwall.
S.	1910.	Hadfield, Sir R. A. (Hon.), Hadfields, Limited, Hecla Works, Sheffield.
E.M.	1927.	Hadfield, S., White Lodge, Keyham, near Leicester.
S.	1927.	Hague, A. P., Murray House, Chesterfield.
Lncs.	1906.	Haigh, J., Swindon Bank Farm, Pannal, near Harrogate.
W. & M.	1924.	Haines, A. D., Penybryn, Tynypwll Road, Whitchurch, Glam.
W.R. of Y.	1919.	Haley, G. H., Nab Wood House, 6, Tower Road, Shipley, Yorks.
L.	1926.	Hall, S., 57, Eden Grove, Horfield, Bristol.
Lncs.	1927.	Hall, T. W., "Ansdel," 7, Greenleach Lane, Worsley, Lancs.
Lncs.	1923.	Hammond, R., 37, Church Road, Smithills, Bolton.
E.M.	1914.	Hammond, Wm., Samson Foundry, Syston, Leicester.
E.M.	1928.	Hammond, Wm., & Co., Ltd., Syston, near Leicester. (Subscribing Firm.)
Lncs.	1904.	Hampson, F. R. (J. Evans & Company), Britannia Works, Cross Street, Blackfriars, Manchester.
S.	1926.	Hampton, C. W., 5, Chorley Drive, Fulwood, Sheffield.
B.	1910.	Harley, A., Ashlea, Stoke Park, Coventry.
B.	1925.	Harper, W. E., Dudley Foundry Co., Ltd., Moor Lane, Brierley Hill. Staffs.
L.	1918.	Harris, A. J. A. (Capt.), "Grovallia," Laburnum Road, Doncaster.
Lncs.	1922.	Harris, F., 18, Holland Street, Padiham.
S.	1928.	Harrison, J., 29, Troughbrook Road, Hollingwood, near Chesterfield.
M.	1926.	Harrod, H., 15, Egglestone Terrace, Stockton-on-Tees.

B'nch.	Year of Election.	MEMBERS.
Gen.	1922.	Harvey, André, 118, Spring Road, Kempston, Bedford.
S.	1909.	Hatfield, W. H., D.Met., The Brown Firth Research Laboratory, Princess Street, Sheffield.
N.	1921.	Hawthorn, Leslie & Company, R. & W. (Subscribing Firm), St. Peter's Works, Newcastle-on-Tyne.
Sc.	1928.	Hay, J., 24, Buchanan Drive, Rutherglen.
L.	1926.	Hearn, J. E., Craig-y-don, West Hill, Luton.
S.	1928.	Hearnshaw, L., "Gleneagles," Manor Road, Brimington, near Chesterfield.
Lncs.	1925.	Heatley, J., 146, Redlam, Blackburn.
L.	1928.	Heeley, W. H., Southern Foundries (1926) Ltd., Purley Way, Croydon, Surrey.
Lncs.	1918.	Helm, R. W., c/o Francis Helm, Ltd., Victoria Foundry, Padiham, Lancs.
Gen.	1926.	Henderson, P.C., M.P., The Right Hon. Arthur (Honorary), 33, Eccleston Square, London, S.W.1.
L.	1928.	Hendra, W., 16, Muncaster Road, West Side Clapham Common, S.W.11.
Lncs.	1923.	Hensman, A. R., 121, Plymouth Grove, Charlton-on-Medlock, Manchester.
N.	1913.	Herbst, M. B., 23, Saltwell View, Gateshead-on-Tyne.
Lncs.	1926.	Hesketh, F., Yarrow Cottage, Broad Lane, Rochdale.
Lncs.	1925.	Hesketh, F. W., 68, Shaw Road, Thornham, Rochdale.
Lncs.	1926.	Hetherington & Sons, Ltd., John, (Subscribing Firm) Vulcan Works, Pollard Street, Manchester.
B.	1926.	Hieatt, H. J., Austin Bungalow, Stone Lane, Kinver, Staffs.
L.	1927.	Hickman, G. E., Greensteps, Park Chase, Guildford.

B'nch.	Year of Election.	MEMBERS.
L.	1926.	Hider, G. E., Upton Foundry, Torquay.
B.	1928.	Hill, S. A., "Hillfields," Bewdley, Gloucester.
S.	1929.	Hinckley, G. P., "Ferndene," Beauchief, Sheffield.
W. & M.	1912.	Hird, B., "Woodcot," Upper Cwmbran, nr. Newport, Mon.
L.	1923.	Hobbs, F. W. G., Standard Brass Foundry, P.O. Box 229, Benoni, Transvaal, S.A.
L.	1929.	Hobkirk, W. B., 26, Bunyan Road, Kempston, Beds.
Sc.	1919.	Hodgart, H. M., Vulcan Works, Paisley.
Lncs.	1923.	Hodgkinson, A., Ford Lane Works, Pendleton, Manchester.
Lncs.	1914.	Hodgson, A., 14, Park Range, Victoria Park, Manchester.
Lncs.	1912.	Hogg, J., 321, Manchester Road, Burnley, Lancs.
B.	1927.	Hole, S. B., "Bourne House," Franchise Street, Wednesbury.
Lncs.	1927.	Hollindrake H. (H. Hollindrake & Sons, Ltd.), Princes Street, Stockport.
L.	1928.	Holmes, W. E., 1, Coronation Road, Plaistow, London, E.13.
B.	1924.	Homer, W. A., 87, Frederick Street, Walsall, Staffs.
Sc.	1914.	Hood, John McLay (Life), 54, Maxwell Drive, Pollokshields, Glasgow.
L.	1927.	Horsman, S. B., 1, Greenhill, Sutton, Surrey.
L.	1927.	Horsman, W. B., 1, Greenhill, Sutton, Surrey.
L.	1920.	Housby, 1., 345, Norwich Road, Ipswich.
Lncs.	1922.	Howard & Bullough, Ltd. (Subscribing Firm), Accrington, Lancs.
Sc.	1923.	Hudson, F., 7, Greenan Road, Kilmarnock.

B'nch.	Year of Election.	MEMBERS.
L.	1924.	Hunt, N. H., c/o Gas Accumulator Co., Ltd. (India); c/o Viartans, 6, Olive Street, Calcutta.
L.	1920.	Hunt, R. J., "Greenhills," Earls Colne, Essex.
N.	1920.	Hunter, Hy., High Cottage, King's Road, Wallsend.
Lncs.	1917.	Hunter, H. E., Barton Hall Engine Works, Patricroft, Manchester.
N.	1919.	Hunter, Summers, C.B.E., J.P., 1, "Dareen," Meadowfield Rd., Stocksfield.
N.	1929.	Hunter, S., junr., 62, Moorside, Fenham, Newcastle-on-Tyne.
B.	1907.	Hurren, F. H., Coventry Malleable, Ltd., Lincoln Street, Coventry.
S.	1920.	Hurst, F. A., Woofindin Avenue, Ranmoor, Sheffield.
Sc.	1927.	Hurst, H., 40, Colinslee Avenue, Lockfield, Paisley.
S.	1914.	Hurst, J. E., Newton Chambers and Co., Ltd., Chapeltown, Sheffield.
L.	1925.	Hutton, R. S., D.Sc., The Greenway, High Wycombe, Bucks.
S.	1911.	Hyde, J. R., A.M.I.Mech.E., "Hillcrest," Clayton Road, Newcastle Staffs.
S.	1922.	Hyde, Robert & Son, Ltd. (Subscribing Firm), North Stafford Steel Works, Stoke-on-Trent.
Sc.	1925.	Hyman, H., Ph.D., 55, Dixon Avenue, Crosshill, Glasgow.
B.	1929.	Ireland, S. L., 875, Pershore Road, Selly Park, Birmingham.
Lncs.	1925.	Jadoul, J. E., 325, Moss Lane East, Manchester.
L.	1925.	James, A. W., 1, Broomhill Road, Ipswich.
L.	1926.	James, J. A., 101, Stoke Road, Slough, Bucks.
L.	1911.	Jarmy, J. R., "Ajaccio," Abbey Road, Leiston, Suffolk.
Sc.	1929.	Jefferson, J., A.R.S.M., Glenmavis, By Airdrie, Scotland.

B'nch.	Year of Election.	MEMBERS.
W. & M.	1928.	Jefferies, J. J., & Sons, Ltd., Holwells Foundry, Hodwell Road, Bristol. (Subscribing Firm.)
Gen.	1927.	Jenkins, A., 29, Invicta Road, Sheerness, Kent.
W. & M.	1924.	Jenkins, T., 51, Tydvil Street, Barry.
S.	1917.	Jenkinson, S. D., Cromwell House, Wincobank, Sheffield.
L.	1904.	Jewson, H., Norwich Road, East Dereham, Norfolk.
L.	1921.	Jewson, K. S., 4, Coopers Terrace, Gearing Road, Dereham, Norfolk.
E.M.	1909.	Jobson, V., Qualcast, Ltd., Derby.
Lncs.	1928.	Johnson, H., Sudan Government Railways, Atbara, Sudan.
Lncs.	1920.	Jolley, W., Breeze Hill, Urmston Lane, Stretford, Manchester.
W. & M.	1928.	Jones, C. E., 65, Cathedral Road, Cardiff.
Lncs.	1922.	Jones, G. A., 54, Fox Street, Edgeley, Stockport.
B.	1925.	Jones, O. P., 25, Rathbone Road, Bearwood, Birmingham.
E.M.	1928.	Jones, J. J., "Southover," Beacon Road, Loughborough.
Lncs.	1927.	Jones, R. A., 36, Wolseley Street, Pendlebury, Manchester.
N.	1929.	Jopling, T. W., "Ash Lea," Thornhill Park, Sunderland.
L.	1927.	Kain, C. H., Lake & Elliott, Ltd., Braintree, Essex.
L.	1928.	Kiao, Kimishna, Mysore Iron Works, Bhadrayati, India.
S.	1921.	Kayser, J. F., 30, Oakhill Road, Nether Edge, Sheffield.
Lncs.	1925.	Kelly, A. T., 31, Windbourne Road, St. Michaels, Liverpool, S.
L.	1917.	Kelly, Jas., 74, Rotherfield Street, N.1.
Lncs.	1922.	Kent, C. W., 9, Dalston Drive, Didsbury.
Lncs.	1919.	Kenyon, H. M., "Sunny Bank," Whalley Road, Accrington.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1910.	Kenyon, M. S., Waterloo, Whalley Road, Accrington.
Lncs.	1904.	Kenyon, R. W.. Entwistle & Kenyon, Limited, Accrington.
S.	1927.	Kessell, C. E. (Vickers Armstrong, Ltd.), River Don Works, Sheffield.
Lncs.	1907.	Key, A. L., 271, Reddish Road, S. Reddish, Stockport.
Sc.	1927.	Kidston, R., Springbank, Falkirk.
B.	1928.	King, A., 14, Alexandra Road, King's Hill, Wednesbury.
Sc.	1914.	King, D., Keppoch Ironworks, Possil Park, Glasgow.
L.	1927.	King, E. G., The Louis Cassier Co., Ltd., 22, Henrietta Street, Covent Garden, London, W.C.2.
Sc.	1904.	King, J., 100, Wellington Street, Glasgow.
W. & M.	1924.	Kinsman, W. S., 116, Miskin Street, Cardiff.
Sc.	1919.	Kinnaird, George, 21, St. Ann's Drive, Giffnock, Glasgow.
S.	1925.	Kitching, W. T., c/o John Fowler, Don Foundry, Sheffield.
L.	1922.	Lake W. B., Lake & Elliot, Ltd., Braintree.
L.	1921.	Lambert, Wesley, "Whitefriars," 41, Bromley Road, S.E.6.
Sc.	1907.	Landale, D. (Life), 36, Great King Street, Edinburgh.
Gen.	1922.	Lane, H. M., 333, State Street, Detroit, Michigan, U.S.A.
Sc.	1928.	Lang, J., Calderside, Jerviston Street, Motherwell.
Gen.	1927.	Langenohl, M., Gelsenkirchen, Bulmkerstr 83, Germany.
L.	1927.	Larke, W. J., Sir, K.B.E., "Eastburn," St. John's Road, Sidcup, Kent.
B.	1927.	Lathe, A., "Westlands," Compton Road, Wolverhampton.
L.	1921.	Lawrence, Geo. D., 5, Clare Road, Leytonstone, E.11.

B'nch	Year of Election.	MEMBERS.
B.	1918.	Layfield, R. P., "Mossfield," Codsall Road, Wolverhampton.
B.	1927.	Lee, C. P., The Municipal Engineering Dept., Municipality, Singapore.
B.	1909.	Lee, Howl & Company, Ltd., Engineers, Tipton.
B.	1926.	Lench, T. C., "The Beeches," Blackheath, Birmingham.
G.	1922.	Leonard, J. (Hon.), 41, Quai du Canal, Herstal, Belgium.
E.M.	1928.	Leys Malleable Castings Co., Ltd., Derby. (Subscribing Firm.)
W.R. of Y.	1922.	Liardet, A. A., Leyland Motors, Ltd., Leyland, Lancs.
N.	1920.	Lillie, G., "Bloomfield," Strathmore Road, Rowlands Gill, Durham.
S.	1913.	Little, J., 20, St. Ann's Square, Manchester.
L.	1922.	Littleton, W. H., 29A, Worbeck Road, Anerley, S.E.20.
B.	1927.	Lloyd, D. C., Stockwell End, Tettenhall, near Wolverhampton.
B.	1926.	Lloyd, W., 285, Arthur Street, Small Heath, Birmingham.
N.	1918.	Logan, A. (R. & W. Hawthorn, Leslie & Company, Ltd.), St. Peter's Works, Newcastle.
S.	1927.	Lomas, A., Red Ridges, Rivelin, near Sheffield.
E.M.	1928.	London Midland & Scottish Railway Co., Euston Station, N.W.1. (Subscribing Firm.)
Lncs.	1921.	Longden, Ed., 158, Manley Road, Manley Park, Manchester.
Sc.	1922.	Longden, J., 11, Drumry Road, Clydebank.
S.	1904.	Longmuir, P., D.Met., 2, Queens Road, Sheffield.
Lncs.	1913.	Longworth, T. P., Moorside, Horrocks Fold, Bolton.
W.R. of Y.	1913.	Loxton, H., Hill Bros., Nevin Foundry, Leeds.

B'nch.	Year of Election.	MEMBERS.
E.M.	1913.	Lucas, J., “Sherwood,” Forest Road, Loughborough.
L.	1921.	Lum, Harry, “Booth-Royd,” Wayville Road, Dartford, Kent.
B.	1928.	Lunt, G. T., “Wayside,” Kingswinford, Staffs.
Sc.	1925.	McArthur, J., “Hawthorn,” Shields Road, Motherwell.
Sc.	1929.	McCance, A., D.Sc., Westview, Uddington.
W. & M.	1922.	McClelland, J. J., “Druslyn,” 81, Bishops Road, Whitchurch, Glam.
Sc.	1919.	McFedries, T., 17, Kirktonholm Street, Kilmarnock.
S.	1916.	McGrah, F. E., 19, Lonsdale Road, Wolverhampton.
L.	1919.	McIntosh, 1, Ecclesbourne Avenue, Duffield, Derby.
Lncs.	1924.	MacKay, M., 109, Edmund Street, Rochdale.
Sc.	1914.	MacKenzie, Alex. D., B.Sc., 35, Braid Road, Edinburgh.
Sc.	1910.	Mackenzie, L. P., 5, Polwarth Terrace, Balcarres Street, Edinburgh.
Sc.	1922.	McKinnon, Gavin, 1477, Dumbarton Road, Scotstoun, Glasgow.
Lncs.	1921.	McLachlan, Jas., 2, Broadoaks Road, Washway Road, Sale, nr. Manchester.
Gen.	1922.	McLain, D. (Hon.), 710, Goldsmith's Buildings, Milwaukee, Wis., U.S.A.
N.	1928.	Mackay, J. S., 5, Wolverleigh Terrace, Gosforth, nr. Newcastle-on-Tyne.
N.	1923.	Mackley, J. R., 20, Beaconsfield Avenue, Low Fell, Gateshead-on-Tyne.
Sc.	1928.	McFarlane, P., Leicester Avenue, Kelvinside, Glasgow.
Lncs.	1923.	McLean, C. G., 14, Jemmett Street, Preston.
Lncs.	1928.	McMinn, G. M., 52, Osborne Road, Levenshulme, Manchester.

B'nch.	Year of Election.	MEMBERS.
Sc.	1928.	McPhail, D., 33, Burlington Avenue, Kelvindale, Glasgow.
N.	1918.	McPherson, T., M.B.E., 53, Percy Park Road, Tynemouth.
B.	1910.	McQueen, D., 6, Anchorage Road, Erdington, Birmingham.
Sc.	1918.	McTurk, J. B., Dorrator Iron Company, Falkirk.
B.	1925.	Maddock, D. W., 21, Waterloo Road, Wellington, Shropshire.
Lncs.	1917.	Makemson, T., 21, Beresford Road, Stretford, Manchester.
S.	1921.	Mander, T. G., Norris Deakin Buildings, King Street, Sheffield.
Lncs.	1919.	Markland, T. W., 327, Tonge Moor Road, Bolton.
L.	1927.	Marley, C., "Harewood," Park Hill Road, Chingford, E.4.
N.	1928.	Marr, J. H., North Biddick Hall, Washington, Co. Durham.
Lncs.	1929.	Marsden, F., "Marshdene," Cecil Road, Hale, Cheshire.
Lncs.	1922.	Marsden & Son, J. (Subscribing Firm), 188, Regent Road, Liverpool.
S.	1922.	Marshall, J., "The Willows," Barrow Hill, Chesterfield.
S.	1928.	Mason, C. L., "Sandygate Towers," Sheffield.
L.	1928.	Mason, J., 123, Waddon Park Avenue, Croydon.
B.	1929.	Mason, N., Alondra Lodge, The Wood, Streetly, Birmingham.
L.	1924.	Mason, W. C., Richardson & Cruddas, Byculla Iron Works, Bombay, India.
B.	1927.	Mason, W. H., The Poplars, 84, Hall Green Street, Bradley, Bilston.
Lncs.	1917.	Masters, J., "The Hollins," Vane Road, Longden Road, Shrewsbury.
L.	1911.	Mather, D. G. (Mather & Smith), Ashford Foundry, Godinton Road, Ashford.

B'nch.	Year of Election.	MEMBERS.
S.	1915.	Mather, T., South View, Carholme Road, Lincoln.
N.	1912.	Mathews, W., 82, St. Peters Road, Holy Cross, Willington Quay-on Tyne.
L.	1926.	Matthieson, R., 37, Closeside, Enfield, Middlesex.
L.	1921.	Mayhew, C. M., 60, Ewesley Road, Sunderland.
Lncs.	1917.	Meadowcroft, Wm. H., 10, Hambledon View, Habergham, Burnley.
Lncs.	1919.	Medcalf, W., 265, Manchester Road, Burnley, Lancs.
B.	1927.	Mees, J. H., 129, King William Street, Stourbridge.
S.	1922.	Melmoth, F. A., "Lyndhurst," Aughton Road, Swallownest, Sheffield.
M.	1926.	Mercer, J. E., Windsor House, Cromwell Terrace, Thornaby-on-Tees.
Lncs.	1912.	Milburn, J., Hawkshead Engineering Works, Workington.
Gen.	1919.	Miles, F. W.
S.	1921.	Miles, R. (Major), Chapeltown, nr. Sheffield.
Lncs.	1916.	Miles, Rd. A., 46, Dean Lane, Newton Heath, Manchester.
Sc.	1928.	Millar, A. C., 24, Hillhead Avenue, Jerviston, Motherwell.
Sc.	1927.	Miller, J., 7, Eildon Villas, Mount Florida, Glasgow.
Lncs.	1918.	Mills, Hilton, 9, Stocks, Alkrington, Middleton, Lancs.
Gen.	1924.	Mills, R. C., 90, Kelsey Street, Waterbury, Conn., U.S.A.
Gen.	1923.	Mitchell, A. M.
Sc.	1920.	Mitchell, W. W., Darroch, Falkirk.
Gen.	1910.	Moldenke, Dr. R. (Hon. Member), Watchung, New York.
N.	1919.	Molineux, W. J., 1, Laburnum Gardens, Low Fell, Gateshead.
L.	1925.	Moore, A. H., Standard Brass Foundry, Benoni, S. Africa.

B'nch.	Year of Election.	MEMBERS.
E.M.	1914.	Moore, H. H., Holmwood, Leicester Road, Loughborough.
L.	1926.	Moorwood, H. S., Onslow House, Sheffield.
W. & M.	1928.	Morgan, A. J., 48, New King Street, Bath.
W. & M.	1928.	Morgan, C. F., 1, Cynthia Villas, Cynthia Road, Bath.
B.	1927.	Moran, G., 18, Bridge Street, West Bromwich.
M.	1927.	Morley, S. H., 13, Peel Street, Thornaby-on-Tees.
N.	1912.	Morris, A., Pallion Foundry, Sunderland.
L.	1925.	Mundey, A. H., Fry's Metal Foundry, 42, Holland Street, S.E.1.
B.	1926.	Murray, J. V., 80, Manor House Road, Wednesbury.
S.	1918.	Newell, Ernest, M.I.Mech.E., The Thorne, Misterton, *via* Doncaster.
B.	1927.	Newsum, A. H., "Enderby," Hadzor Road, Warley Woods, Birmingham.
N.	1912.	Newton, J. W., Flora House, Cobden Street, Darlington.
Lncs.	1920.	Newton, Sam, Linotype & Machinery Ltd., Altrincham.
N.	1927.	Nicholson, F. W., 30, Addison Road, Heaton, Newcastle-on-Tyne.
L.	1924.	Nikaido, Y. (Lieut.-Com.), Kiro Naval Works, Kure, Japan.
N.	1913.	Noble, H., "The Cedars," Low Fell, Co. Durham.
B.	1927.	Norbury, A. L., D.Sc., 24, St. Paul's Square, Birmingham.
L.	1927.	Norman, G. L., Basinghurst, Nightingale Road, Guildford.
S.	1923.	North, The Hon., J. M. W., "Elmwood," Old Whittington, Chesterfield.
N.	1921.	North-Eastern Marine Engineering Company Ltd. (Subscribing Firm), Wallsend-on-Tyne.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1918.	Oakden, E., A.M.I.C.E., Further Hey Woodley, nr. Stockport.
L.	1917.	O'Keefe, Wm., 62, Stanhope Street, Birmingham.
N.	1920.	Oliver, R., 35, Edith Street, Jarrow-on-Tyne.
Lncs.	1921.	Ormerod, J., 24, Barrett Street, Bury.
S.	1913.	Osborn, S., Clyde Steel Works, Sheffield.
L.	1906.	Oswald, J., Sleaford Foundry, Nine Elms Lane, S.W.8.
L.	1919.	Otto, C. A., 22, Owenite Street, Abbey Wood, S.E.2.
B.	1918.	Oubridge, W. A., M.I.M.E. (British Piston Ring Company, Limited), Holbrook Lane, Foleshill, Coventry.
S.	1921.	Oxley, G. H., Vulcan Foundry, Attercliffe Road, Sheffield.
S.	1915.	Oxley, G. L., Vulcan Foundry, Attercliffe, Sheffield.
S.	1910.	Oxley, W., Vulcan Foundry, Attercliffe, Sheffield.
N.	1921.	Palmer's Shipbuilding & Iron Company Ltd. (Subscribing Firm), Hebburn-on-Tyne.
W.R. of Y.	1922.	Parker, W., 271, Meadow Head, Woodseats, Sheffield.
E.M.	1905.	Parker, W. B., 3, Murray Road, Rugby.
W.R. of Y.	1907.	Parkinson, J., Shipley, Yorks.
S.	1924.	Parramore, A., Caledonian Foundry, Chapeltown, Sheffield.
N.	1915.	Parsons, Hy. F., "Avondale," Heaton Park View, Heaton, Newcastle.
L.	1927.	Pateman, W. J., 18, Gloucester Road, Luton.
N.	1912.	Patterson, R. O., Thorneyholme, Wylam-on-Tyne.

B'nch.	Year of Election.	MEMBERS.
Sc.	1929.	Paul, J., Meadow View Cottage, Bridgend, Bathgate, West Lothian.
N.	1912.	Paulin, W. J., 1, Stannington Grove, Heaton, Newcastle.
E.M.	1924.	Peace, A. E., Claremont, Littleover Hollow, nr. Derby.
B.	1924.	Pearce, J. G., M.Sc., Director, British Cast Iron Research Assn., 24, St. Paul's Square, Birmingham.
E.M.	1913.	Pearson, N. G. (Lieut-Col.), Beeston Foundry Company, Ltd., Beeston, Notts.
Lncs.	1909.	Pell, J., 17, Mersey Street, Rosegrove, Burnley, Lancs.
Lncs.	1922.	Pellatt, D. L., "Whitethorn," Lostock, Bolton.
M.	1926.	Pennington, D. G., Lea Close, Middleton St. George, Co. Durham.
Lncs.	1927.	Penrose, J., 190, Horsedge Street, Oldham.
S.	1929.	Perkins, C. B., 4, Wilton Place, Collegiate Crescent, Sheffield.
L.	1918.	Perkins, J. E. S., "Hilmorton," The Park, Peterborough.
B.	1920.	Perks, C., Phœnix Castings, Ltd., Coventry.
Lncs.	1919.	Perryman, W., 17, Hurst Street, Bury.
L.	1926.	Pisek, Dr. Mont. Fr. Technical High School, Brno, Czechoslovakia.
L.	1926.	Petters, Ltd. (Subscribing Firm), Westland Works, Yeovil.
Gen.	1927.	Phillips, E. A., Laceby, near Grimsby.
B.	1929.	Pitt, D., 53, Solihull Lane, Hall Green, Birmingham.
Lncs.	1922.	Place, J. H., Station Road, Simonstone, nr. Padiham, Lancs.
E.M.	1922.	Pochin, R. E., 246, Fosse Road, South Leicester.
Lncs.	1922.	Pollard, J. T., 7, Powell Street, Burnley.
Lncs.	1926.	Poole, J., "Clevelands," Bury New Road, Whitefield Manor.

B'nch.	Year of Election.	MEMBERS.
W.R. of Y.	1922.	Poole, W. H., Kings Grove, Villa Road, Bingley, Bradford.
S.	1923.	Porter, H. W., 78, Ringinglow Road, Sheffield.
L.	1919.	Pott, L. C., 38b, Baron's Court Road, London, W.14.
E.M.	1924.	Potter, W. C., "Kenwalyn," Sykefield Avenue, Leicester.
S.	1926.	Presswood, C., B.A., "Crowgate," South Anston, nr. Sheffield.
S.	1908.	Prestwich, W. C., "The Hallowes," Dronfield, Sheffield.
L.	1926.	Prior, W. H., 62, Andalus Road, London, S.W.9.
L.	1912.	Primrose, H. S., 17, Victoria Street, London.
Sc.	1920.	Primrose, James M., Mansion House Road, Falkirk.
Lncs.	1912.	Primrose, J. S. G., 17, Salisbury Road, Chorlton-cum-Hardy, Manchester.
B.	1924.	Pritchard, P., "Eastcote," St. Agnes Road, Moseley, Birmingham.
E.M.	1904.	Pulsford, F. C., "Kenmore," Sandown Road, Leicester.
L.	1928.	Quicke, J. H., c/o Leocock, Madeira (The Madeira Supply Co., Ltd., Oficinas, Mecanicas, S.E. Fundicao, Rue de Ponte de S. Lazara, N.4).
Gen.	1922.	Ramas, E. (Honorary), 2, Rue de Constantinople, Place de l'Europe, Paris.
L.	1926.	Randle, L. A., 83, Cambridge Street, Stafford.
N.	1912.	Rang, H. A. J., 2, St. Nicholas Buildings, Newcastle-on-Tyne.
Sc.	1923.	Rattray, W. J., c/o Burns & Co., Ltd., Howrah, Bengal, India.
S.	1921.	Rawlings, Geo., 67, Huntley Road, Sheffield.
M.	1928.	Reay Brass Foundry Co., Ltd., Eagle Works, Skinner Street, Stockton-on-Tees. (Subscribing Firm.)

B'nch.	Year of Election.	MEMBERS.
W. & M.	1927.	Rees, Ivor, 27, Allington Road, Southville, Bristol.
Sc.	1920.	Rennie, A., “Kilnside,” Falkirk.
Sc.	1927.	Rennie, W., “Ardenlea,” Cumbernauld, Dumbartonshire.
Lncs.	1919.	Rhead, E. L., Prof. (Honorary), College of Technology, Manchester.
Gen.	1923.	Rhydderch, A., Lenton Sands, Robertson Place, Vaucluse, Sydney, Australia.
W. & M.	1925.	Richards, C. E., 53, Merches Gardens, Grange, Cardiff.
W. & M.	1924.	Richardson, R. J., Rosemary, Lan Park, Pontypridd.
Lncs.	1919.	Richardson, W. B., Hope Foundry, Farnworth, nr. Bolton.
Sc.	1911.	Riddell, M., Dungoyne, 35, Aytoun Road, Pollokshields, Glasgow.
M.	1926.	Ridsdale, N. D., 3, Wilson Street, Middlesbrough.
M.	1926.	Ritchie, R. J. H., Cambridge House, Linthorpe, Middlesbrough.
B.	1923.	Roberts, E., 117, Radford Road, Leamington.
B.	1919.	Roberts, G. E., “Rosedale,” Earlsdon Avenue, Coventry.
Lncs.	1921.	Roberts, G. P., 153, Brandlesholme Road, Bury, Lancs.
Sc.	1922.	Robertson, Donald M., “Kinfauns,” High Station Road, Falkirk.
Lncs.	1927.	Robinson, F. O. “Braemar,” Birchfield Road, Widnes.
W.R. of Y.	1908.	Robinson. J. G., 17, Gibraltar Road, Halifax.
Sc.	1929.	Rodger, J. M., & Son, Kyle Foundry, Ayr, Scotland. (Subscribing Firm.)
Lncs.	1912.	Roe, S., 23,Grantham Street, Oldham.
Gen.	1909.	Ronceray, E. (Hon.), 3, Rue Paul Carle, Choisy-le-Roi, Seine, Paris, France.
W.R. of Y.	1928.	Roper, E. A., Thorn Cottage, Bogthorn, Oakworth Road, Keighley.

B'nch.	Year of Election.	MEMBERS.
Gen.	1925.	Ropsy, P. A., 27, Rue Dodoens, Antwerp, Belgium.
B.	1923.	Roxburgh, W., 271, Clifton Road, Rugby.
S.	1918.	Russell, F., c/o General Refractories Company, Limited, Wicker Arches, Sheffield.
E.M.	1924.	Russell, P. A., 88, Dulverton Road, Leicester.
E.M.	1906.	Russell, S. H., Bath Lane, Leicester.
N.	1915.	Sanderson, F., 15, Handyside Arcade, Newcastle-on-Tyne.
S.	1921.	Sandford, J., 46, Clifford Road, Sheffield.
N.	1915.	Saunders, J., Borough Road Foundry, Sunderland.
W.R. of Y.	1922.	Sayers, H., 53, Acre Road, Middleton, Leeds.
B.	1921.	Scampton, Chas., South Avenue, Stoke Park, Coventry.
M.	1927.	Scholes, A., Alma House, Junction Road, Norton-on-Tees.
N.	1929.	Scott, W., 8, Wilson Street, Dunston-on-Tyne.
Lncs.	1927.	Seddon, W. E., 14, Samuel Street Rochdale.
B.	1910.	Sexton, A. Humbolt (Hon. Life), 6, Clarendon Road, St. Helier, Jersey, C.I.
Sc.	1920.	Sharpe, Daniel, 100, Wellington St., Glasgow.
Lncs.	1927.	Shaw, A., 52, King Street, Oldham.
N.	1929.	Shaw, G., 4, Elm Grove, Forest Hall, Newcastle-on-Tyne.
L.	1906.	Shaw, J., "Cartref," Parkstone Avenue, Southsea.
N.	1907.	Shaw, R. J. (Life), 26, Queens Road, Monkseaton, Northumberland.
M.	1922.	Shaw, W. (Subscribing Firm), Wellington Cast Steel Foundry, Middlesbrough.

B'nch.	Year of Election.	MEMBERS.
S.	1908.	Sheepbridge C. & I. Company, Limited (Subscribing Firm), Sheepbridge Works, Chesterfield.
L.	1927.	Shepherd, H. H., c/o Crane Bennett, Ltd., Nacton Works Ipswich, Suffolk.
Lncs.	1907.	Sherburn, H. (Life), "Ellesmere," Padgate, Warrington.
Lncs.	1905.	Sherburn, W. H. (Life), Rotherwood, Stockton Heath, Warrington.
L.	1912.	Shillitoe, H., "Westwood," Potter's Bar, N.
N.	1920.	Shipley, H. J., East Cottage, Delacour Road, Blaydon-on-Tyne.
S.	1927.	Shirt, F. A., 317, Psalter Lane, Sheffield.
Lncs.	1907.	Simkiss, J., Abington House, Hyde Road, Gorton, Manchester.
N.	1913.	Simm, J. N., 61, Marine Avenue, Monkseaton.
Lncs.	1924.	Simpson, H., 102, Edmund Street, Rochdale.
L.	1927.	Simpson, H. L., "Brockenhurst," 4, Emlyns Street, Stamford, Lincs.
S.	1926.	Singleton, T., 21, Peveril Road, Sheffield.
Sc.	1926.	Skinner, F. J., Lochend House, Maryhill, Glasgow.
W.R. of Y.	1921.	Slingsby, W., Highfield Villa, Keighley.
L.	1925.	Small, F. G., "Meliden," Burden Lane, Cheam, Surrey.
N.	1921.	Smalley, O., Miramer Hotel, Brooklyn, New York, U.S.A.
Sc.	1927.	Smart, G., Rowallan Stepps, Glasgow.
L.	1928.	Smeeton, J., 15, Victoria Street, S.W.1.
S.	1922.	Smith, A., "Oakroyd," Dodworth Road, Barnsley.
B.	1928.	Smith, A. B., "Bramber," Histone Hill, Bodsall, Staffs.
S.	1922.	Smith, A. Qualter, "Lynwood," Dodworth Road, Barnsley.

B'nch.	Year of Election.	MEMBERS
B.	1925.	Smith, B. W., Heath Farm, Marston Green, Birmingham.
Lncs.	1928.	Smith, C. G., "Craigside," Well Lane, Hr. Bebbington, Cheshire.
B.	1919.	Smith, C. R. (Messrs, C. & B. Smith), Stewart Street, Wolverhampton.
S.	1921.	Smith, Fredk., Devonshire Villas, Barrow Hill, nr. Chesterfield.
E.M.	1921.	Smith, George, Cavendish Place, Beeston, Notts.
N.	1905.	Smith, J., "Harton Lea," Harton, South Shields.
M.	1926.	Smith, J. D., 19, Shaftesbury Street, Stockton-on-Tees.
N.	1917.	Smith, J. E., 7, Lily Avenue, Jesmond, Newcastle.
M.	1926.	Smith, J. L., "Holmesdale," Billingham, nr. Stockton-on-Tees.
N.	1922.	Smith Patterson & Company, Limited (Subscribing Firm), Pioneer Works, Blaydon-on-Tyne.
N.	1913.	Smith, R. H., 16, Whitburn Road, East, Cleadon, nr. Sunderland.
B.	1928.	Smith, W. H., "Exford," Lenwade Road, Warley Woods, Birmingham.
B.	1925.	Smith, W. S., 15, Broadfields Road, Erdington, Birmingham.
L.	1923.	Snook, S. W. G., 30, Lawrence Road, Tottenham, N.15.
L.	1914.	Sommerfield, H. G., Charterhouse Chambers, Charterhouse Square, London, E.C.1.
Lncs.	1926.	Southerst, R., 8, Raven Street, Bury.
S.	1925.	Spafford, Arnold V., Imperial Works, Brown Street, Sheffield.
Lncs.	1927.	Spedding, O. L., Holly Grove, Dobcross, R.S.O., Yorks.
E.M.	1914.	Spiers, T. A., "Delamere," Uppingham, Road, Leicester.
E.M.	1928.	Stanton Ironworks Co., Ltd., Stanton, near Nottingham. (Subscribing Firm.)

B'nch.	Year of Election.	MEMBERS.
Lncs.	1927.	Stanworth, J., M.B.E., "The Woodlands," Rimington, Clitheroe.
Lncs.	1922.	Staveley Coal & Iron Company (Subscribing Firm), Staveley Works, nr. Chesterfield.
S.	1927.	Steele, F. E., 66, Hatfield House Lane, Firth Park, Sheffield.
Sc.	1920.	Steven, A. W., Lauriston Ironworks, Falkirk.
E.M.	1914.	Stevenson, E., "Charnwood," Sunnydale Road, Carlton, Notts.
E.M.	1928.	Stobart, W., 20, Kenilworth Avenue, Normanton, Derby.
N.	1912.	Stobie, V., Oakfield, Ryton-on-Tyne.
L.	1915.	Stone, E. G., 20, Cantley Avenue, Clapham Common, S.W.4.
L.	1912.	Stone, J., 106, Harlaxton Road, Grantham.
Gen.	1922.	Stones, J., 2, Marshall Road, Agarpara, Kamarhatti P.O., Calcutta, India.
E.M.	1916.	Street, W., 20, Burleigh Road, Loughborough.
Lncs.	1921.	Stubbs, Limited, Jos. (Subscribing Firm), Mill Street Works, Ancoats, Manchester.
Lncs.	1912.	Stubbs, Oliver (Hon. Life), (J. Stubbs, Limited), Openshaw, Manchester.
Lncs.	1919.	Stubbs, R. W., 209, Dickenson Road, Longsight, Manchester.
Lncs.	1928.	Studley, G. C., 34, Wood Road North, Old Trafford, Manchester.
N.	1921.	Stothard, A., 32, Grainger Street, West, Newcastle.
M.	1927.	Styles, W. E., Eskdale House, Cambridge Road, Thornaby-on-Tees.
W.R. of Y.	1922.	Summerscales, W. H. G., Rockfield, Keighley.
E.M.	1927.	Summersgill, E., (Senior) 47, Station Road, Long Eaton, Notts.
W.R. of Y.	1919.	Summersgill, H., Stanacre Foundry, Wapping Road, Bradford.

B'nch.	Year of Election.	
L.	1927.	Sutton, E. W., 48, Halesworth Road, Lewisham.
Gen.	1926.	Swaine, G., c/o Marshall, Sons & Co., India, Ltd., Argarpara Works, Karnarhatty, P.O. 24, Parganas, Bengal, India.
S.	1908.	Swinden, T., D.Met., 26, Oakhill Road, Nether Edge, Sheffield.
N.	1928.	Swinney, T., Castle View, Morpeth.
W.R. of Y.	1912.	Sykes, J. W., Birdacre House, Gomersall, Leeds.
Lncs.	1927.	Tait, W., Mere, Repetition Castings (M/c), Ltd., Holland Street, Miles Platting, Manchester.
E.M.	1928.	Taite, G., The Old Manor House, Lutterworth.
N.	1927.	Tate, C. B., 32, Grosvenor Drive, Whitley Bay.
Lncs.	1924.	Taylor, A., 84, Hornby Road, Blackpool.
N.	1919.	Taylor, C. R. R., Manor House, South Shields.
N.	1922.	Taylor & Son, Limited, C. W. (Subscribing Firm), North Eastern Foundries, South Shields.
Lncs.	1911.	Taylor, R. (Asa Lees & Company, Limited), Oldham.
N.	1925.	Taylor, T., Point Pleasant Hall, Wallsend-on-Tyne.
Lncs.	1920.	Thompson, H., 6, Dobson Road, Bolton.
W.R. of Y.	1922.	Thornton, W. G., 1,081, Grangefield Avenue, Thornbury, Bradford.
L.	1924.	Thornycroft and Co., Ltd., John I. (Subscribing Firm), Iron Foundry, Woolston Works, Southampton.
M.	1926.	Thorpe, S. P., 14, Park Terrace, Stockton-on-Tees.
L.	1925.	Tibbenham, L. J., The Limes, Stowmarket.
W. & M.	1928.	Timmins, D., 1, Westbourne Road, Caston, Bristol.

B'nch.	Year of Election.	MEMBERS.
M.	1926.	Todd, H., 175, Southfield Road, Middlesbrough.
L.	1927.	Tompkins, S. J., Sefton, Birmingham Road, Wylde Green, Birmingham.
S.	1927.	Tonge, J., Bovey Court, Vereeniging, S. Africa.
Gen.	1922.	Touceda, E. (Hon.), 943, Broadway, Albany, N.Y., U.S.A.
Lncs.	1921.	Town End Foundry Ltd. (Subscribing Firm), Chapel-en-le-Frith, Derbyshire.
S.	1929.	Townsend, C. W. D., Wrawby, Briggs, Lincs.
Lncs.	1928.	Toy, H., 4, Westmorland Road, Urmston, Manchester.
M.	1924.	Toy, S. V., The Ridge, Saltburn-by-the-Sea.
N.	1927.	Travers, D. Le M., 29, Clayton Road, Newcastle.
L.	1922.	Tremayne, Chas., 26, Eversley Road, Charlton, S.E.7.
Sc.	1922.	Tullis, D. R., Aillig, Campbell Drive, Bearsden, Glasgow.
L.	1926.	Turner, A. C., 144, Turney Road, Dulwich, S.E.24.
B.	1927.	Turner, H. L., 23, Mellish Road, Walsall.
B.	1910.	Turner, Prof. T. (Hon. Member), Netheridge Elm Drive, Leatherhead, Surrey.
B.	1927.	Turner, T. H., M.Sc., 17, Acacia Road, Bournville, Birmingham.
Sc.	1923.	Tutchings, A., 152, Greenhead Drive, South Govan, Glasgow.
Lncs.	1909.	Tweedales & Smalley, Limited, Globe Works, Castleton, Lancs.
L.	1928.	Twigg, W. R., The Laurels, Harpenden, Herts.
B.	1918.	Tyson, E. H., 269, Gillott Road, Edgbaston, Birmingham.
S.	1916.	Underwood, G. H., "Kulti," Cutthorpe, nr. Chesterfield.

B'nch.	Year of Election.	MEMBERS.
So.	1913.	Ure, G. A. (Smith & Wellstood, Ltd.) Bonnybridge, Scotland.
Gen.	1927.	Vanzetti, Comm. Img. Carlo, C.B.E., General Manager, Fonderia Milanese di Acciaio, Milan, Italy.
Gen.	1922.	Varlet, J. (Hon.), Esperance Longdoz Works, Liége, Belgium.
S.	1924.	Varma, J. P., 3, Bingham Park Crescent, Sheffield.
Lncs.	1922.	Vickers, Limited (Subscribing Firm), Barrow-in-Furness.
S.	1917.	Village, R., Bircholme, Dronfield, nr. Sheffield.
Sc.	1911.	Waddell, R. C., 2, Percy Street, Ibrox, Glasgow.
L.	1911.	Walker, C. F., 42, Windsor Street, Wolverton, Bucks.
S.	1907.	Walker, E., Effingham Mills, Rotherham.
Lncs.	1924.	Walker, J. S. A., Major, Walker Bros., Ltd., Wigan.
M.	1926.	Walker, T., Hazebronck, Old Thornaby, Stockton-on-Tees.
S.	1918.	Walker, T. R., B.A., 26, Castlewood Road, Fulwood, Sheffield.
E.M.	1929.	Wallis, J., 5, Matlock Road, Ambergate, Derbyshire.
N.	1921.	Wallsend Slipway & Engineering Co., Ltd. (Subscribing Firm), Wallsend-on-Tyne.
Gen.	1922.	Walters, A. F. (H. I. Dixon & Company, Limited), The Omiar Founding Eng. Company, Limited, Love Lane, Mazagon, Bombay, India.
N.	1927.	Walton, S. H., 73, Highbury, Jesmond, Newcastle-on-Tyne.
S.	1908.	Ward, A. J. (T. W. Ward, Limited), Albion Works, Saville Street, Sheffield.
S.	1914.	Ward, J. C., Oak Park, Manchester Road, Sheffield.
L.	1919.	Wares, F. J., 216, Cromwell Road, Peterborough.

B’nch.	Year of Election.	MEMBERS.
N.	1919.	Watson, J. H., Benwell Grange, Avenue, Newcastle-on-Tyne.
W.R. of Y.	1922.	Watson, Jos. J., “Gwynfa,” College Street, East, Crosland Moor, Huddersfield.
B.	1914.	Watson, R., 49, York Street, Rugby.
B.	1917.	Webb, B., 531, Stourbridge Road, Scott Green, Dudley.
L.	1925.	Webster, F. K., Deptford Star Foundry, Rolt Road, Deptford, London, S.E.8.
B.	1928.	Webster, G. R., 8, Marlborough Road, Bearwood, Birmingham.
Sc.	1920.	Weir, Rt. Hon. Lord, The, P.C., D.L., LL.D. (Life Member), G. and J. Weir, Limited, Cathcart, Glasgow.
N.	1912.	Weir, J. M., 7, Stanhope Road South Shields.
W.R. of Y.	1908.	Welford, R. D., 1, Hilton Road, Frizinghall, Bradford.
S.	1910.	Wells, G. E. (Edgar Allen & Co., Limited), Imperial Steel Works, Sheffield.
S.	1914.	Wells, J. A. E., “Thrift House,” Ringinglow Road, Sheffield.
Gen.	1927.	Werner, S. G., Da Dng. Dusseldof, Lindernannstr 18, Germany.
Lncs.	1926.	West, Walter, 12, The Crescent, Leyland, Lancs.
S.	1921.	Wharton, E., Rosemont, Station Road, Brimington, Chesterfield.
N.	1913.	Wharton, J., Phœnix Foundry, Maryport, Cumberland.
B.	1928.	White, A. O., 9, Longcroft Avenue, Wednesbury.
W.R. of Y.	1928.	White, H. H., “Rydalhurst,” Church Lane, Crosscrates, Leeds.
B.	1925.	Whitehouse, E. J., “The Knoll,” Penn, Wolverhampton.
S.	1916.	Whiteley, A., 7, Glen Road, Nether Edge, Sheffield.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1910.	Whittaker, C., & Company, Limited, Dowry Street Ironworks, Accrington.
W.R. of Y.		Whittaker, F., Greyholme, Horsforth, Yorks.
B.	1919.	Wild, M., 29, Beauchamp Avenue, Leamington.
B.	1921.	Wilkinson, D., 1,114, Bristol Road South, Northfield, Birmingham.
W.R. of Y.	1919.	Wilkinson, G. (E. & W. Haley, Ltd.), Thornton Road, Bradford.
Lncs.	1917.	Wilkinson, R., "Lyndhurst," Wargrave Road, Newton-le-Willows, Lancs.
B.	1928.	Wilks, L. P., Rydal Mount, Fowler Street, Wolverhampton.
W. & M.	1924.	Williams, R. G., "Rossmore," Calcot Road, Barry.
W. & M.	1916.	Williams, W., Alexandra Brass Foundry, East Dock, Cardiff.
L.	1927.	Williams, W. L., 61, Grenville Road, Braintree, Essex.
M.	1912.	Wilson, F. P., "Parkhurst," Middlesbrough.
E.M.	1928.	Wilson, P. H., Ivy Mount, Nottingham.
L.	1927.	Windsor, W. T., "Pax," Coggershall Road, Braintree, Essex.
Sc.	1906.	Winterton, H., "Moorlands," Milngavie, Dumbartonshire.
S.	1924.	Winterton, H. T., "The Beild," Newlands Road, Chesterfield.
W.R. of Y.	1912.	Wise, S. W., 110, Pullan Avenue, Eccleshill, Bradford.
B.	1925.	Wiseman, Alfred, Ltd. (Subscribing Firm), Glover Street, Birmingham.
L.	1927.	Withers, E. C. (Com.), 73, Warwick Road, Earl's Court, S.W.5.
B.	1919.	Wood, D. Howard (Capt.), Kingswood Park, Moseley, Birmingham.
B.	1909.	Wood, E. J. (Patent Axlebox and Foundry Company, Limited), Wednesfield Foundry, Wolverhampton.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1926.	Woodcock, A., 163, Hartington Street, Moss Side, Manchester.
W.R.	1914.	Worcester, A. S., Toria House, 162, Victoria Street, Lockwood, Huddersfield.
L.	1928.	Wrey, C. R. B., 37a, Thurloe Place, London, S.W.7.
B.	1914.	Wright, E. N. (Life), Oxford Lodge, Penn Fields, Wolverhampton.
E.M.	1928.	Wright, W. H., 190, London Road, Leicester.
E.M.	1927.	Wyborn, S., 35, Hartington Road, Sherwood, Notts.
Lncs.	1928.	Yarwood, W. J., & Co., Ltd., The Dock, Northwich, Cheshire. (Subscribing Firm.)
L.	1914.	Young, H. J., F.I.C., 3, Central Buildings, Westminster, S.W.1.

ASSOCIATE MEMBERS.

W.R. of Y.	1928.	Ablard, A., 231, Folkstone Street, Bradford Moor, Bradford.
M.	1926.	Adcock, F. H., 7, Beech Grove, Middlesbrough.
Sc.	1919.	Affleck, J., B.Sc., 21, Overdale Avenue, Langside, Glasgow.
L.	1929.	Ainsworth, E., 22, Whittingstall Road, Fulham, S.W.6.
W.R.	1927.	Ackeroyd, H., 40, Devonshire Street, Keighley.
B.	1915.	Aldridge, S., 91, Dale Street, Walsall.
B.	1928.	Allen, A. E., 7, The Drive, Gravelly Hill, Birmingham.
B.	1925.	Allen, Wm., Chuckery Foundry, Walsall, Staffs.
S.	1927.	Alford, A. L., 408, Windmill Lane, Shiregreen, Sheffield.
M.	1929.	Alston, J., c/o 75, Lanehouse Road, Thornaby-on-Tees.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
M.	1928.	Anderson, D., "Nutana," Victoria Avenue, Redcar, Yorks.
Sc.	1926.	Anderson, J. Y., 35, Alice Street, Paisley.
Lncs.	1907.	Andrew, F., 643, Oldham Road, Failsworth, Manchester.
L.	1925.	Armishaw, W. J., 44, Common View, Letchworth, Herts.
E.M.	1928.	Armitage, R., 24, St. Paul's Road, Derby.
M.	1926.	Armstrong, G., 23, Chipchase Street, Middlesbrough.
L.	1925.	Armstrong, L. R., 56, Parliament Hill Mansions, N.W.6.
Sc.	1926.	Arnott, James, 114, Broomhall Road, Newlands, Glasgow.
Lncs.	1916.	Ashton, F., 24, Isherwood Street, Heywood, Lancs.
Lncs.	1927.	Ashton, N. C., 591, Chorley New Road, Horwich, near Bolton.
Lncs.	1923.	Astall, D., 7, Gambrell Bank Road, Smallshaw, Ashton-under-Lyne.
L.	1905.	Aston, D. A., 36, Bastwick Street, Goswell Road, London, E.C.1.
Lncs.	1922.	Atkinson, Albert, 11, Guy Street, Padiham, Lancs.
S.	1916.	Atkinson, F., "Woodlands," Richmond Road, Handsworth, Sheffield.
N.	1925.	Atkinson, G., 10, Queen's Drive, Whitley Bay.
S.	1920.	Avill, Wm., Lyndon House, Mumsbro' Lane, Greasbro', Rotherham.
S.	1912.	Ayres, J. A., "Aldbourne," Ecclesfield, Sheffield.
Sc.	1918.	Bacon, A. H., 228, Saracen Street, Possilpark, Glasgow.
S.	1924.	Bacon, P., 86, Bridge Street, Swinton, nr. Rotherham.
Lncs.	1926.	Bagley, J., 34, Guest Street, Leigh, Lancs.
S.	1909.	Bailey, P. T., 17, Hallowes Lane, Dronfield. nr. Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1916.	Bain, W., Ardmore, Bonnybridge, Scotland.
Sc.	1928.	Baird, T. C., 87, Main Street, Barrhead.
B.	1918.	Baker, W., "Kara Gwent," Coalway Road, Penn Fields, Wolverhampton.
W.R. of Y.	1927.	Balme, H., 22, Pinewood Grove, Marsden, nr. Huddersfield.
Lncs.	1927.	Barber, C., 43, Birch Street, West Gorton, Manchester.
M.	1926.	Barclay, D., 45, Edward Street, Stockton-on-Tees.
S.	1922.	Barker, A. G., 26, Victoria Road, Balby, Doncaster.
B.	1919.	Barker, S. B., 34, Darby Road, Coalbrookdale, Salop.
S.	1924.	Barker, W., 136, Nidd Road, Attercliffe, Sheffield.
S.	1913.	Barnaby, N. F. (John Brown & Company, Limited), Scunthorpe.
Lncs.	1910.	Barnes, G., 16, Tremellen Street, Accrington.
Lncs.	1915.	Baron, E., 24, Grimshaw Lane, Newton Heath, Manchester.
L.	1914.	Barrett, H. G., Letchworth Castings Co., Letchworth, Herts.
Lncs.	1924.	Barrett, S., 150, Chorley New Road, Horwich, nr. Bolton.
L.	1911.	Batch, J., 60, Robertson Street, Queen Street, Battersea, S.W.11.
B.	1927.	Bate, F., 48, Sweetpool Lane, West Hagley, Stourbridge.
B.	1904.	Bather, H. K. (Chamberlain & Hill), Chuckery Foundry, Walsall.
S.	1920.	Batty, F., 52, Hampton Road, Pitsmoor, Sheffield.
E.M.	1926.	Baxter, J., 108, Stone Hill Road, Derby.
Scot.	1929.	Baxter, M., Whittinghame Place, Bridgend, Bathgate.
L.	1921.	Baxter, Percy L., 131, Ampthill Avenue, Benoni, Transvaal, S. Africa.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R. of Y.	1924.	Bean, E., c/o Anglo-Persian Oil Co., Abadan, Persia.
L.	1925.	Beardshaw, A., 50, Jackmans Place, Letchworth, Herts.
W.R. of Y.	1923.	Beaumont, G., 25, Oxley Street, Pontefract Lane, Leeds.
E.M.	1919.	Beck, H. J., Barton House, Rosamonde Ride, Littleover, Lane Derby.
L.	1925.	Becker, M. L., National Physical Laboratory, Teddington.
Lncs.	1927.	Beech, T. L., 86, Cyprus Street, Stretford, Manchester.
W.R. of Y.	1927.	Beilby, A. R., 233, Melrose Gate, Tang Hall, York.
N.	1925.	Bell, J., 65, Park Avenue, Whitley Bay, Northumberland.
Sc.	1910.	Bell, T., 2, Bellfield Street, Barrhead, Glasgow.
S.	1918.	Bennett, A. M., 12, Brandon Grove, Newton Park, Leeds.
W. & M.	1928.	Bennett, S. L., 2, Lily Street, Roath Park, Cardiff.
W.R. of Y.	1912.	Berry, F., 125, Watkinson Road, Illingworth, Halifax.
Lncs.	1917.	Berry, R. I., 31, Bury Road, Bamford, Rochdale.
B.	1926.	Bettinson, J. S., Woodbourne Lodge, Edgbaston, Birmingham.
S.	1928.	Betts, F., 69, Tapton Bank, Crosspool, Sheffield.
Lncs.	1926.	Bevins, J., 1, Little Union Street, Ulverston.
Sc.	1920.	Binnie, Alex., 15, Cochrane Buildings, Pleasance Square, Falkirk.
B.	1916.	Birch, H., Inglewood, Chester Road, Streetly, Birmingham.
B.	1922.	Bird, J. B., "Corallyn," Hardwick Road, Streetly, nr. Birmingham.
Sc.	1919.	Black, A., 10, Prince Edward Street, Crosshill, Glasgow.
Sc.	1928.	Black, J., 20, Watling Street, Camelon, Falkirk.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1928.	Blackadder, T., 5, Orchard Street, Falkirk.
Sc.	1928.	Blackadder, W., Linton Vale, Meeks Road, Falkirk.
E.M.	1921.	Blackham, E. L., 460, Uttoxeter Road, Derby.
E.M.	1920.	Blackwell, Wm., 36, Arthur Street, Loughborough.
Sc.	1910.	Blackwood, R., "Kenilworth," Johnstone, Glasgow.
E.M.	1919.	Blades, C., The Vines, Wanlip Road, Syston, Leicester.
Sc.	1928.	Blair, W. W., Station House, Grahamston, Falkirk.
E.M.	1924.	Bloor, F. A., "Inglemere," Stenson Road, Derby.
N.	1919.	Blythe, J. D., 81, Northumberland Terrace, Willington-Quay-on-Tyne.
W.R. of Y.	1922.	Booth, G. E., 80, Institute Road, Eccleshill, Bradford, Yorks.
S.	1928.	Booth, J. T., Ringwood Road, Brimington, Chesterfield.
S.	1928.	Booth, W. A., 46, John Street, Brampton, Chesterfield.
N.	1915.	Borthwick, T., Crookhall House, Consett, Co. Durham.
Lncs.	1928.	Bose, R. N., 24, Church Street, Stretford, Manchester.
M.	1920.	Bound, W. H., Wh. Ex. A.M.I. Mech.E., 12, Dufton Road, Linthorpe, Middlesbrough.
S.	1927.	Boulton, D. C., 4, Littlemoor Crescent, Newbold, Chesterfield.
Lncs.	1921.	Bowden, J., 72, Grange Road, Chorlton-cum-Hardy, Manchester.
L.	1906.	Bowman, A., 48, Lathom Road, East Ham, E.6.
W. & M.	1926.	Boxall, H. A., 33, Gellydeg Street, Maesycummer-via-Cardiff.
W.R. of Y.	1929.	Bradbury, H., 33, Perseverence Street, Primrose Hill, Huddersfield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1916.	Bradley, H., "Cotswold," Bocking Lane, Woodseats, Sheffield.
B.	1925.	Bradshaw, J. H. D., 4, Foley Street, Wednesbury, Staffs.
L.	1928.	Brand, J. P., 43, Hampden Road, Kingston-on-Thames.
N.	1921.	Brass, A., 44, Haydn Terrace, Gateshead-on-Tyne.
Sc.	1928.	Breckenridge, J. M., 7, Orchard Street, Kilmarnock.
Lncs.	1923.	Brereton, C. F., c/o Mrs. Oldham, 25, Manchester Road, Chorlton-cum-Hardy, Manchester.
Lncs.	1917.	Brierley, A., 76, Ash Road, Denton, Manchester.
Lncs.	1923.	Brockbank, A. H., 3, Hawkens Street, Old Trafford, Manchester.
W.R. of Y.	1926.	Brook, J., 10, Elford Terrace, Roundhay Road, Leeds.
Lncs.	1925.	Broughton, H., 1, Chip Hill Road, Deane, Bolton.
N.	1917.	Brown, C. Hy., 57, Whitehall Road, Gateshead-on-Tyne.
L.	1917.	Brown, E. H., 91, Devonshire Road, Forest Hill, S.E. 23.
Lncs.	1923.	Brown, G. H., 17, Derbyshire Avenue, Stretford, Manchester.
Lncs.	1917.	Brown, J., 227, Milnrow Road, Rochdale.
Sc.	1929.	Brownlee, J., 2, Atholl Terrace, Bathgate, Scotland.
Sc.	1914.	Bruce, A., 6, Lockharton Avenue, Torpichen Street, Edinburgh.
Sc.	1928.	Bruce, W., 38, Watson Street, Falkirk.
Sc.	1926.	Bruce, W. T., 6, Lockharton Avenue, Edinburgh.
S.	1928.	Bryan, J., 30, St. Helens Street, Chesterfield.
Sc.	1927.	Bryden, Walter Myreton, Bonnybridge, Stirlingshire.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1926.	Buck, A., 9, St. Paul's Road, Blackpool, N.S.
N.	1920.	Buckham, G. H.. "Harewood," Grange Road, Newcastle-on-Tyne.
L.	1926.	Buckingham, F. A. T., 114, Richmond Road, Gillingham, Kent.
E.M.	1928.	Buckland, R. H., 20, Dairyhouse Road, Derby.
L.	1928.	Bullock, D. C., 29, Clarendon Road, Harrow, Middlesex.
B.	1925.	Bullows, W. D., c/o Castings, Ltd., Selbourne Street, Walsall, Staffs.
E.M.	1928.	Bulmer, G. N. B., 11, Station Road, Challaston, Derby.
E.M.	1929.	Burgess, A. E., 21, Foundry Cottages, Syston, Leicestershire.
E.M.	1928.	Burgess, F., 21, Foundry Cottages, Syston, nr. Leicester.
E.M.	1929.	Burgess, S. H., 137, North Street, Barrow-on-Sour, near Loughborough.
S.	1924.	Burkinshaw, J. W., 13, Laverack Street, Handsworth, Sheffield.
Sc.	1917.	Burns, J. K., 77, Sandy Road, Renfrew.
N.	1925.	Burrell, J., 2, Bede Crescent, Willington-Quay-on-Tyne.
W.R. of Y.	1921.	Butterfield, P., 10, Eastfield Place, Sutton-in-Craven, Keighley, Yorks.
E.M.	1927.	Butters, F. G., 1, Albany Street, Ilkeston.
Sc.	1928.	Butters, F. H. R., 145, Hillend Road, Lambhill, Glasgow.
Lncs.	1923.	Butterworth, A. W., 214, Frederick Street, Werneth, Oldham.
Lncs.	1919.	Butterworth, J., 40, Clement Royds Street, Rochdale.
W.R. of Y.	1921.	Butterworth, John, 79, Bracewell Drive, Wheatley Road, Halifax.
Lncs.	1929.	Buttriss, J. O., 27, Niobe Street, Walney Island, Barrow-in-Furness.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1920.	Buxton, J., 68, Luke Lane, Hurst, Ashton-u.-Lyne.
Lncs.	1926.	Cairns, F., 59, Brodwell Street, Seedley, Manchester.
B.	1924.	Callaghan, G. M., 6, Foxgrove, Acocks Green, Birmingham.
E.M.	1929.	Callis, B., 57, Clarence Street, Loughborough.
S.	1920.	Cameron, N., Cavendish Villas, Devonshire Road, Totley Rise, nr. Sheffield.
Lncs.	1926.	Campbell, A. B., 125, Stamford Road, Audenshaw, Manchester.
Sc.	1912.	Campbell, D. McGregor, Torwood Foundry, Larbert.
L.	1914.	Campbell, J., 9, Western Gardens, Ealing, W.
Lncs.	1918.	Campbell, W., 12, Denbeigh Street, Stockport.
S.	1927.	Carlisle, E. A., 3, Silver Hill Road, Ecclesall, Sheffield.
Lncs.	1925.	Carr, H., 7, Lord Street, Stalybridge.
L.	1921.	Carrell, Hy. Alfred, 6J, Peabody Buildings, Farringdon Road, E.C.1.
W.R. of Y.	1927.	Carter, S., Cowley Lane, Lepton, nr. Huddersfield.
W.R. of Y.	1923.	Carver, W., 112, Valley Road, Pudsey, near Leeds.
Sc.	1928.	Chambers, H., c/o Macpherson, 20, Douglas Street, Paisley.
S.	1925.	Chambers, J. F., 31, Duke Street, Staveley, Chesterfield.
W.R. of Y.	1922.	Chappelow, Thos., 181, Taylor Street, Batley, Yorks.
Sc.	1921.	Charters, J., 12, Walworth Terrace, Glasgow.
Lncs.	1925.	Cheetham, E., 5, Eldon Road, Edgeley, Stockport.
W. & M.	1928.	Chilvers, W., High Street, Crowmarth, nr. Wallingford.
Lncs.	1927.	Clark, J. J., 39, Dicconson Street. Ormskirk, Lancs.

B'nch.	Year of Election	ASSOCIATE MEMBERS.
N.	1920.	Clark, J. W., 133, St. Thomas' Terrace, Blaydon-on-Tyne.
Sc.	1928.	Clark, R. F., c/o Robertson, 12, Clarence Street, Paisley.
L.	1923.	Clark, W., 9, Jubilee Road, Basingstoke.
E.M.	1929.	Clark, W., 256, Cossington Road, Sileby, Leicester.
N.	1912.	Clarke, J., Albert Street, Tayport, Fife.
L.	1925.	Clarke, J. W., 17, Major Walk, Peterborough.
Sc.	1928.	Clarkson, A., Liddle's Buildings, Stenhousemuir, Scotland.
Sc.	1922.	Cleverley, A.M., B.Sc., 24, York Street, Falkirk, Scotland.
Lncs.	1928.	Cliffe, J., 43, Manley Road, Oldham.
Lncs.	1921.	Coleman, J. I., West Dene, Brooklyn Road, Wilpshire, Blackburn.
W. & M.	1926.	Coles, F. L., 15, Moon Street, Cardiff.
S.	1920.	Coles, W. H., 2, Gordon Avenue, Woodseats, Sheffield.
S.	1916.	Collins, B. L., P.O. Box 290, Johannesburg, South Africa.
W.R. of Y.	1926.	Collinson, K. H., 11, Grandmere Place, Halifax.
S.	1907.	Cook, A. H., W. Cook & Sons, Ltd., Washford Road, Sheffield.
E.M.	1916.	Cook, F., 168, Woods Lane, Derby.
Sc.	1929.	Cook, T., 28, James Street, Ladywell, Motherwell, Scotland.
S.	1914.	Cook, W. G., Washford Road, Sheffield.
Lncs.	1927.	Cooke, J. E., 116, Derbyshire Avenue, Stretford.
Lncs.	1926.	Cooke, T., 15, Finchley Road, Hale, Cheshire.
M.	1926.	Cooper, A., 50, Upper Oxford Street, South Bank.
N.	1919.	Corbett, W. A., "Dinguardi," Bungalow 19, High Farm Estate, Wallsend-on-Tyne.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1926.	Coupe, Wm., junr., 36, Kittlingborne, High Walton, nr. Preston.
Lncs.	1929.	Crabtree, J. E., 23, Buxton Street, Accrington.
Sc.	1919.	Cree, A., 160, Mount Amnan Drive, King's Park, Cathcart, Glasgow.
E.M.	1926.	Creese, H. J., 112, Mere Road, Leicester.
Lncs.	1910.	Critchley, F., 631, St. Helens Road, Bolton.
L.	1928.	Cropley, H. J., 28, Beach Road, Gorleston-on-Sea, Great Yarmouth.
S.	1912.	Critchley, T., 52, Limpsfield Road, Brightside, Sheffield.
Lncs.	1928.	Cross, J., 80, Elmfield Street, Church.
Lncs.	1929.	Cryer, F., 29, Thirlmere Avenue, Stretford, Manchester.
Lncs.	1927.	Cullinmore, G., 15, Lincoln Square, Farnworth, Widnes.
B.	1906.	Curnow, M. H., 41, Cemetery Lane, West Bromwich.
Sc.	1926.	Currie, J., 1, Sutherland Crescent, Bathgate.
B.	1907.	Dalrymple, D., 20, Beeches Road, West Bromwich.
S.	1920.	Darby, A., 5, Dobbin Hill, Greystones, Sheffield.
Lncs.	1927.	Dathathraya, D., 219, Residency Bazaar, Hyderabad, Deccan, India.
Sc.	1922.	Davidson, W. B. (Jas. Keith & Blackman Co., Ltd.), Arbroath.
W. & M.	1924.	Davies, E. H., 224, Cardiff Road, Aberaman.
Sc.	1926.	Davis, Thos., 633, Dumbarton Road, Partick, Glasgow.
L.	1914.	Davis, W. H., 8, Pye Street, Portsmouth.
W. & M.	1928.	Dawson, J. A., 1, Greenhill Place, Thrupp, near Stroud, Gloucestershire.
S.	1922.	Day, A. B., 19, Scarsdale Road, Dronfield, near Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1925.	Dean, J., 48, Northgate Road, Stockport.
Lncs.	1924.	Deeley, F., 52, Bewsey Street, Warrington.
Lncs.	1918.	Demaine, F. C., 9, Rising Sun Lane, Garden Suburb, Oldham.
Lncs.	1922.	Demaine (jun.), F. C., 56, Bolton Street, Oldham.
M.	1926.	Denwood, W., 7, Pearl Street, Haverton Hill, Middlesbrough.
W.R. of Y.	1922.	Derrington, H., 101, Norfolk Mount, Halifax.
L.	1909.	Derry, L. B., 3, Preston Road, Yeovil, Somerset.
B.	1925.	Dexter, B. J., 80, New Rowley Street, Walsall.
E.M.	1929.	Dexter, G., 10, Barrow Road, Sileby, Leicester.
Sc.	1928.	Dickie, W., 19, Glasgow Road, Paisley, Scotland.
N.	1916.	Dickinson, S., 39, Givens Street, Roker, Sunderland.
B.	1920.	Dicks, G. E., 110, Richmond Hill, Langley, near Birmingham.
S.	1914.	Dixon, A. F., 9, Bristol Road, Sheffield.
L.	1916	Dobson, J., 3, Bond Isle Terrace, Stanhope, Co. Durham.
N.	1924.	Dodds, J., 64, Scotswood Road, South Benwell, Newcastle-on-Tyne.
Lncs.	1921.	Dolphin, J. H., 47, Heaton Avenue, Bolton.
W. & M.	1924.	Domville, S., St. Marie, New Main Road, Rumney, Monmouth.
Sc.	1919.	Donaldson, J. W., D.Sc., Scott's Shipbuilding and Engineering Company, Limited, Greenock.
L.	1928.	Donnon, W., 6, Wilfrid Gardens, North Acton, W.3.
Sc.	1919.	Dorsie, J. C., Maplewood, Kirkintilloch.
B.	1920.	Dubberley, F., 44, Great Arthur Street, Smethwick, Staffs.

B'nch	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1925.	Duckworth, J. A., 42a, Ormerod Street, Accrington.
Lncs.	1924.	Dudley, Wm., 11, Barlow Street, Lower Openshaw, Manchester.
Lncs.	1929.	Dunkerley, W., 42, Balfour Street, Oldham.
Lncs.	1929.	Dunleavy, F., 457, Bury Road, Bolton.
E.M.	1929.	Dunn, E., 72, King Street, Sileby, Leicester.
L.	1920.	Dunn, J. W., 50, Marlow Road, East Ham, E.7.
W. & N.	1928.	Durrant, G. A., 11, West Park Road, Newport.
Lncs.	1913.	Eastwood, J. H., 83, Princess Street, Castleton, nr. Manchester.
S.	1929.	Eaton, A., 2, Littlewood Street, Hexthorpe, Doncaster.
L.	1912.	Eccott, A. E., The Elms, 68, Smithies Road, Plumstead, S.E.18.
S.	1925.	Edginton, J., 3, Coupe Road, Burngreave, Sheffield.
Sc.	1911.	Edmiston, M., Rose Vale, Windsor Road, Renfrew.
W.R. of Y.	1922.	Edmondson, J., 107, Woodroyd Road, West Bowling, Bradford.
B.	1922.	Edwards, F. C., 32, Queen's Head Road, Handsworth, Birmingham.
E.M.	1925.	Elder, A., 90, Stenson Road, Derby.
Sc.	1927.	Elder, P., 10, Napier Crescent, Bainsford, Falkirk.
E.M.	1928.	Ellis, E. D., 195/7, Berridge Road, Nottingham.
L.	1922.	Ellis, J. P., 20, Lambourn Road, Clapham, S.W.4.
E.M.	1909.	Ellson, J., 19, Derby Road, Ripley, Derby.
S.	1924.	Emmott, J., 33, Bowood Road, Sheffield.
Sc.	1920.	Erskine, N. A. W., Morton Cottage, Camelon.
L.	1929.	Etheredge, R. W. E., 21, Hillside, Harlesden, N.W.10.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1924.	Evans, H., 93, Second Avenue, Trafford Park, Manchester.
L.	1927.	Everest, A. B., B.Sc., Ph.D., The Bureau of Information on Nickel, Ltd., 2, Metal Exchange Buildings, Leadenhall Avenue, London, E.C.3.
Sc.	1928.	Ewing, W., 25, Clifford Street, Bellahouston, Glasgow.
W.R. of Y.	1922.	Farrar, Levi, 22, Springswood Ave., Shipley, Yorks.
Lncs.	1919.	Farrow, C., 84, Louisa Street, Openshaw, Manchester.
Lncs.	1922.	Faulkner, Thos., 95, Bank Street, Clayton, Manchester.
Lncs.	1924.	Fellingham, T. R., 81, Henshaw Street, Stretford, Manchester.
N.	1918.	Fender, B., 15, Kenilworth Road, Monkseaton, Northumberland.
L.	1924.	Fenn, J. H., 25, Francemary Street, Brockley, S.E.4.
Sc.	1929.	Ferguson, T., 81, Commercial Road, Barrhead, Scotland.
Sc.	1912.	Ferlie, T., Steel and Iron Founder, Auchtermuchty, Fifeshire.
S.	1927.	Firth, T. C., Storth Oaks, Ranmoor, Sheffield.
L.	1926.	Fish, F. W., 30, The Crescent, Letchworth, Herts.
Lncs.	1922.	Fist, Thomas, 127, Hughes Street, Hallewell, Bolton.
N.	1922.	Flack, E. W., 3, Falshaw Street, Washington Station, Co. Durham.
B.	1927.	Flavel, S. W. B., 11, Avenue Road, Warwick Street, Leamington Spa.
B.	1918.	Flavell, W. J., Carter's Green Passage, West Bromwich.
Lncs.	1919.	Flitcroft, E., School Hill Ironworks, Bolton.
E.M.	1925.	Food, F. H., 108, Upper Conduit Street, Leicester.
W.R. of Y.	1924.	Foster, H., 10, Highfield Place, Bramley, Leeds.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1912.	Fowler, T. E., 72, Station Road, New Southgate, N.11.
W.R. of Y.	1928.	Fowler, S., 30, Victoria Road, Halifax.
Gen.	1923.	Fox, F. S., 6333, Tuxeda Avenue, Detroit, Michigan, U.S.A.
B.	1928.	Fox, N. J., 225, Birmingham Road, Walsall.
Lncs.	1924.	Frith, W., 8, Buckley Street, Ashton New Road, Clayton, Manchester.
N.	1920.	Futers, R. Wm., 23, Brannen Street, North Shields.
E.M.	1925.	Gale, B., 15, Ridgway Street, Nottingham.
Sc.	1904.	Galt, J., Henry & Galt, Sneddon Foundry, Paisley.
B.	1920.	Gaunt, J. W., 101, Beeches Road, West Bromwich.
L.	1927.	Gerrard, J. Norbreck, Alexandra Road, Peterborough.
Lncs.	1927.	Gibson, T., 11, Lincoln Street, Haslingden, Blackburn.
E.M.	1926.	Gill, F., 31, Serlby Rise, Gordon Road, Nottingham.
Sc.	1927.	Gillepsie, H. Mc. K., "Stenhouse," Carron, Falkirk.
Sc.	1928.	Gillespie, C., 67, Commercial Road, Barrhead.
Lncs.	1923.	Gilpin, W., "Sunnyside," Birch Grove, Rusholme, Manchester.
E.M.	1924.	Gilson, A. J., 12, Hampden Street, Derby.
M.	1926.	Gleave, J., 1, Victoria Street, Haverton Hill, Middlesbrough.
W.R. of Y.	1922.	Gledhill, F., 205, East View, Bradford Road, Brighouse, Yorks.
B.	1917.	Glynn, T. A., Jesmond, Fair View Avenue, Hamstead, Birmingham.
Lncs.	1924.	Goodwin, G. W., 64, Roseneath Road, Urmston, Manchester.
E.M.	1919.	Goodwin, T., Brae Side, New Bedford Street, Derby.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1922.	Gospel, W., Gutta Percha Co., c/o The Staffordshire Stainless Iron Co., Ltd., Baldwin Street, Bilston, Staffs.
Sc.	1919.	Graham, R., 116, Stratford Street, Maryhill, Glasgow.
E.M.	1917.	Grant, George, 62, Leicester Road, Quorn, nr. Loughborough.
Sc.	1912.	Gray, J., 2, Station Road, Dumbarton.
E.M.	1929.	Greasley, A. O., 20, High Street, Barrow-on-Sour, nr. Loughborough.
E.M.	1928.	Greatorex, H., 149, Brook Street, Derby.
S.	1925.	Greaves, H. A., 25, Raven Road, Nether Edge, Sheffield.
S.	1924.	Greaves, J., 3, New Houses, Piccadily, Chesterfield.
S.	1919.	Greaves, J. B., 77, Spooner Road, Broomhill, Sheffield.
S.	1924.	Green, A., 201, Doncaster Road, Rotherham.
Lncs.	1924.	Green, A. E., 66, Wolseley Road, Preston.
S.	1914.	Green, P., 54, Rolleston Road, Firth Park, Sheffield.
Lncs.	1927.	Greenhalgh, A., 20, Orchard Street, Heywood, Lancashire.
Lncs.	1920.	Greenhalgh, W., 86, Crosby Road, Bolton.
M.	1926.	Greenwell, O., 12, Angle Street, Grove Hill, Middlesbrough.
Lncs.	1924.	Greenwood, T., 1, Schofield Street, Todmorden.
L.	1926.	Gregory, A. W., 98, Ashton Road, Luton.
L.	1918.	Gregory, E., 16, Mansfield Road, Beech Hill, Luton.
W. & M.	1928.	Griffin, L., 83, Holloway, Bath.
B.	1926.	Griffiths, A. G., 56, Runnymede Road, Hall Green, Birmingham.
E.M.	1924.	Griffiths, S., 94, Stenson Road, Derby.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
M.	1926.	Griffiths, W., Valley View, Station Road, Amersham, Bucks.
Lncs.	1919.	Grimwood, E. E. G., 129, Glebelands Road, Ashton-on-Mersey.
Lncs.	1912.	Grundy, H. V., Pentrich, Campbell Road, Brooklands, Cheshire.
L.	1920.	Gurney, S. J., 24, Burns Road, Battersea, S.W.
M.	1926.	Hackwood, J., 52, Byelands Street, Middlesbrough.
Sc.	1920.	Haig, T., 8, Cardrook Terrace, Muirhall Road, Larbert, Scotland.
S.	1909.	Hall, E. D., 50, Napier Street, Sheffield.
L.	1921.	Hall, Geo., "Glenthorne," Swan Hill, Oxton, Birkenhead.
N.	1914.	Hall, J. J., "Ellesmere," King George's Road, Cullercoats.
E.M.	1925.	Hallamore, J. C., Oak Farm, Burton Road, Littleover, nr. Derby.
Lncs.	1929.	Halliday, E., 88, Harcourt Street, Preston.
E.M.	1925.	Halloran, J., 152, Brook Street, Derby.
Sc.	1925.	Hamil, W., 50, Woodhead Avenue, Kirkintilloch.
W.R. of Y.	1927.	Hammond, D. W., 63, Waverley Road, Great Horton, Bradford.
B.	1924.	Hammond, G. A., 13c, Hill Top, West Bromwich, Staffs.
E.M.	1928.	Hancock, A. J., "Eversley," Western Road, Mickleover, Derby.
E.M.	1925.	Hancock, D., 43, Drewry Lane, Derby.
B.	1927.	Hand, A. F., 18, Holyhead Road, Oakengates, Salop.
L.	1918.	Hand, H. E., 189, Manwood Road, Crofton Park, S.E.4.
E.M.	1924.	Hanson, C. H., 285, Abbey Street, Derby.
W. & M.	1927.	Hares, A., Park Crescent, 648, Stapleton Road, Bristol.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1927.	Harford, A. E., 85, Sumatra Road, West Hampstead, N.W.6.
Lncs.	1926.	Hargraves, R. C., 32, Parsonage Street, Stockport.
Lncs.	1919.	Hargraves, R. R. (Grandridge and Mansergh, Ltd.), Wheathill Street, Salford, Manchester.
M.	1927.	Harper, F. A., "The Briars," Bishopton Road, Stockton-on-Tees.
Lncs.	1911.	Harper, H., 28, Alexandra Street, Castleton, nr. Manchester.
B.	1927.	Harper, J., 113, Mansfield Road, Aston, Birmingham.
L.	1925.	Harrington, W. T., 21, Vernon Road, Stratford, London, E.15.
W. & M.	1929.	Harris, T. R., 41, Roskear Road, Camborne, Cornwall.
Lncs.	1929.	Harrison, A., 54, Cheadle Street, Openshaw, Manchester.
M.	1926.	Harrison, A. G., 127, Norton Avenue, Norton-on-Tees.
W.R. of Y.	1928.	Harrison, H., 7, St. Leonards Road, Girlington, Bradford.
Sc.	1916.	Harrower, J. (Bo'ness Iron Company), Bo'ness, Scotland.
L.	1927.	Hart, W. F., "The Gables," Cressing Road, Braintree, Essex.
Sc.	1914.	Hartley, R. F., London Road Foundry, Edinburgh.
M.	1926.	Harvey, D., 4, Rydal Road, Stockton-on-Tees.
S.	1926.	Hatton, W. H., Broomhall Lane, Sheepbridge, Chesterfield.
W. & M.	1928.	Hawes, W., "Ben Trovato," Whittecks Road, Hanham, Bristol.
E.M.	1925.	Hawley, T. H., 53, Willow Brook Road, Leicester.
Sc.	1928.	Hawthorne, S., 10, Clarence Street, Paisley.
Sc.	1910.	Hay, J., 120, Brownside Road, Cambuslang, Glasgow.
B.	1910.	Hayward, G. T., 120, Gillott Road, Edgbaston, Birmingham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1923.	Hayward, R., 39, Belgrave Road, New Moston, Manchester.
E.M.	1922.	Hayward, Wm., Virginia Cottage, Uffington Road, Stamford, Lincs.
Lncs.	1925.	Heatley, H., "Woodville," Livesey Branch Road, Blackburn.
W.R. of Y.	1925.	Heaton, B., Messrs. Hall & Stell, Dalton Lane, Keighley.
B.	1906.	Heggie, C., 79, Holly Lane, Erdington, Birmingham.
Lncs.	1922.	Henderson, G., 1120, Eleventh Street, Trafford Park, Manchester.
L.	1910.	Henderson, G. B., 28, College Road, Woolston, Southampton.
Sc.	1928.	Henderson, J., 10, Windsor Place, Newmains, Lanarkshire.
N.	1923.	Henderson, J. W., c/o Singapore Harbour Board, Keppel Harbour, Singapore, Straits Settlements.
Sc.	1911.	Henderson, R., 67, Love Street, Paisley.
Sc.	1921.	Henry, John, 75, Alma Street, Grahamston, Falkirk.
Lncs.	1922.	Henshaw, J. E., "Trefechan," Hyde Road, Woodley.
L.	1928.	Herring, A., 30, Heathview Road, Thornton Heath, Surrey.
E.M.	1920.	Hey, James Wm., 43, Howe Street, Derby.
B.	1927.	Hibbert, J. C., 39, Montague Road, Erdington, Birmingham.
L.	1925.	Hickenbottom, W. J., 50, Waterloo Road, Dunstable.
Lncs.	1915.	Hill, A., 114, Middleton Road, Heywood, Lancs.
Lncs.	1925.	Hill, H. G., 495, Stretford Road, Old Trafford, Manchester.
E.M.	1917.	Hilton, H. J. S., 29, West Avenue, Derby.
B.	1921.	Hinley, Geo. H., 53, Park Lane East, Tipton, Staffs.
W.R. of Y.	1928.	Hions, T. H., Raw Hill, Rastrick, Brighouse.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R. of Y.	1922.	Hird, W., The Corner, Harden, Bingley, Yorks.
N.	1928.	Hodges, A. E., 11, Camperdown Street, Gateshead.
W.R. of Y.	1927.	Holdsworth, H., 62, Wood Lane, Fire Lane Ends, Bradford.
E.M.	1926.	Holland, G., Costock, nr. Loughborough.
S.	1920.	Holland, G. A., Red House, Clay Cross, near Chesterfield.
Lncs.	1922.	Holland, W., 157, Barton Road, Stretford, Manchester.
Lncs.	1924.	Holt, H., 41, Carmen Street, Ardwick, Manchester.
Lncs.	1925.	Hopwood, A., Water Lane, Wilmslow, Cheshire.
E.M.	1928.	Horton, S. A., 3, Becher Street, Derby.
L.	1921.	Hotchkis, J. D., 29, Romberg Road, London, S.W.17.
Lncs.	1924.	Howard, E. J. L., 8, Queens Terrace, Clarence Road, Longsight, Manchester.
Lncs.	1921.	Howcroft, J., 5, St. James' Street, New Bury, Farnworth, nr. Bolton.
W. & M.	1922.	Howe, C. A., G. I. P. Loco Works, Parel. Bombay, India.
W. & M.	1929.	Howell W., 41, Monthemer Road, Cardiff.
L.	1927.	Howell, L. H., Vanbrugh Hill House, 1a, Vanbrugh Hill, Blackheath, London, S.E.3.
S.	1917.	Hoy, R. E., 33, Brunswick Avenue, Beverley Road, Hull.
Lncs.	1926.	Hudson, R., 39, St. Andrew Avenue, Droylesden, Lancashire.
B.	1924.	Hulse, J. C., 51, Westbourne Street, Walsall.
Lncs.	1928.	Humpage, A. J., 69, Mancot Lane, Mancot Royal, Queen's Ferry, Chester.
S.	1925.	Hunt, A., 18, Hollingwood Common, Barrow Hill, nr. Chesterfield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1926.	Hunter, J. M., 77, Prestwick Road, Ayr.
L.	1923.	Hunter, R. L., "Kirkmailing," East Cote Road, Ruislip, Middlesex.
L.	1922.	Husselbury, E., Rosemead, Winifred Road, Bedford.
L.	1924.	Hutchings, T. C., 10, Lopen Road, Silver Street, Edmonton, London, N.18.
L.	1927.	Hyde, F. E., 22, Volta Road, Swindon.
B.	1925.	Hyde, Sidney, 25, Inhedge, Upper Gornal, near Dudley.
Lncs.	1928.	Ingham, T., 225, Manchester Road, Denton.
Lncs.	1917.	Inskip, A., 992, Ashton Old Road, Openshaw, Manchester.
Sc.	1920.	Irvine, A., The Point, King Street, Larbert, N.B.
B.	1925.	Jackson, A., 73, First Street, Low Moor, Bradford.
Lncs.	1925.	Jackson, A., 27, Marlboro' Street, Accrington.
W.R. of W.	1928.	Jackson, C. E., 5, Chaucer Street, Hull Road, York.
Lncs.	1923.	Jacques, T., The Cottage, Hill Top, Romiley, nr. Stockport.
B.	1914.	James, W., 96, Grove Lane, Handsworth, Birmingham.
L.	1925.	Jarvis, B., 30, Princes Street, Dunstable, Beds.
N.	1919.	Jay, H. C., 32, Bayswater Road, West Jesmond, Newcastle-on-Tyne.
Sc.	1927.	Jeffrey, R. S. M., Lithgow Avenue, Kirkintilloch.
S.	1929.	Jervis, T. A., East Drayton, Retford, Notts.
B.	1919.	Johnson, J. B., 27, Ball Fields, Tipton.
M.	1926.	Johnson, L., 45, Lanehouse Road, Thornaby-on-Tees.
B.	1924.	Johnston, W. L., 49, Gough Road, Coseley, nr. Bilston, Staffs.
Lncs.	1916.	Jones, J. H., "Elleray," Temple Drive, Swinton, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS
Lncs.	1928.	Jones, W., 112, St. Mark's Road, Saltney, Chester.
Lncs.	1919.	Jowett, H., 9, Dacre Street, Morpeth.
Lncs.	1922.	Kay, Wm., 9, Eastbank Street, Bolton, Lancs.
W.R. of Y.	1922.	Kaye, H., 6, Fryergate Terrace, New Scarboro', Wakefield.
Lncs.	1907.	Kemlo, R. W., "Dunottar," Campbell Road, Brooklands, Cheshire.
Sc.	1912.	Kennedy, J., "Dunard," Howieshill, Cambuslang.
M.	1929.	Kennedy, W. D. M., 13, Bon Lea Terrace, Thornaby-on-Tees.
E.M.	1918.	Kerfoot, John, 23, Cumberland Road, Loughborough.
Sc.	1929.	Kerr, H. F., 25, Gideon Street, Bathgate, Scotland.
Sc.	1914.	Kerr, W., 101, Ardgowan Street, Glasgow.
Lncs.	1925.	Kershaw, J., 31, Birkdale Street, Cheetham Hill, Manchester.
E.M.	1927.	Kershaw, T. F., 15, Sandford Road, Syston, nr. Leicester.
Lncs.	1927.	Kidd, S. (Junior), 4, St. Stephen's Street, Oldham.
Sc.	1928.	Kidston, W., The Bengal Iron Co., Kulti, E.I.R., India.
Sc.	1927.	Kilpatrick, A., Block 8, Foundry Street, Carron Road, Falkirk.
N.	1925.	Kirby, A. D., 6, Falshaw Street, Washington Station, Co. Durham.
Lncs.	1924.	Kirkham, J., 13, Gt. James Street, W. Gorton, Manchester.
W.R. of Y.	1922.	Kirkbride, A. D., 24, Springswood Avenue, Shipley, Bradford, Yorks.
Sc.	1920.	Kirkwood, J., 102, Boyd Street, Govanhill, Glasgow.
B.	1922.	Kitchen, B., 1, Hughes Avenue, Birches Barn Road, Wolverhampton.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1929.	Knagg, W. D., 41, Grosvenor Place, Ashton-on-Ribble.
Lncs.	1927.	Knight, J., 112, Winwick Road, Warrington.
S.	1908.	Knowles, J. (c/o. Walkers), Manchester Road, Stocksbridge, Sheffield.
B.	1927.	Lafford, T. W., 8, Pensnett Road, Brierley Hill.
Lncs.	1923.	Laing, J., 59, Victoria Road, Bedford,
Lncs.	1927.	Lally, W., 60, Clovelly Road, Worsley Road, Swinton.
Sc.	1922.	Lang, Wm., 64, Second Avenue, Radnor Park, Clydebank.
Sc.	1907.	Lawrie, Alex., 20, McKinlay Place, Kilmarnock.
Sc.	1919.	Lawrie, R. D., 49, Thorncliffe Lane, Chapeltown, Sheffield.
Lncs.	1914.	Leaf, J. W., District Bank House, Castleton, nr. Rochdale.
N.	1913.	Lee, J., 38, Point Pleasant Terrace, Wallsend-on-Tyne.
Gen.	1921.	Leech, Wm. Creighton (N.S.W. Gov. Railways), Wentworth and Rutledge Street, Eastwood, Sydney, N.S.W.
S.	1925.	Levesley, Wm., 32, Westbourne Road, Broomhill, Sheffield.
B.	1919.	Lewis, D. (John Harper & Company, Limited), Albion Works, Willenhall, Staffs.
B.	1925.	Lewis, E. J., 45, Grafnant, Church Vale, West Bromwich.
B.	1910.	Lewis, G., Strathmore, Paget Road, Wolverhampton.
E.M.	1928.	Lewis, S., 122, Brighton Road, Derby.
W.R. of Y.	1926.	Liddemore, A. E., 4, Park Avenue, Long Park, Keighley.
Sc.	1925.	Liddle, R., 117, Roseberry Street, Oatlands, Glasgow.
Lncs.	1927.	Liley, M., 64, Buxton Crescent, Turf Hill Estate, Rochdale.
E.M.	1923.	Limbert, H., 15B, Factory Street, Loughborough.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1925.	Lineker, A. W., Ruddington House, Beaconsfield, C.P., South Africa.
L.	1919.	Lisby, T., 7, Meanley Road, Manor Park, E.
N.	1919.	Little, J. E. O., 1, Gibson Terrace, Maryhill, Dundee.
Sc.	1910.	Littlejohn, A., 39, Rupert Street, Glasgow, N.W.
Lncs.	1928.	Livesey, J., 16, Finchley Street, Moston, Manchester.
Lncs.	1925.	Lockett, E., 38, Jackson Street, Gorton, Manchester.
N.	1928.	Livingstone, J., 40, Dunstan Road, Dunston-on-Tyne.
W.R. of Y.	1922.	Lowe, E., 35, Foster Road, Ingrow, Keighley, Yorks.
E.M.	1927.	Lowe, H., "Rose Cottage," Queenborough, nr. Leicester.
Lncs.	1927.	Lowe, J., 175a, Dill Hall Lane, Church, near Accrington.
Lncs.	1910.	Lupton & Sons, H. E., Scaithcliffe Works, Accrington.
W.R. of Y.	1927.	Loxton, C. R., 26, Elmet Avenue, Roundhay, Leeds.
Sc.	1928.	Lumsden, G., 42, Gavin Street, Motherwell.
B.	1908.	Mace, C., 64, Port Street, Manchester.
Lncs.	1927.	Martin, W., 34, St. George's Road, Withington, Manchester.
Sc.	1926.	McArthur, J. N., 12, Hamilton Drive, Hillhead, Glasgow, W.2.
Sc.	1928.	McArthur, W., 47, Start Avenue, Camelon, Falkirk.
N.	1919.	McBride, T. B., 8, Stanwick Street, Tynemouth.
Sc.	1910.	McCall, J. J., 162, Cambridge Drive, N. Kelvinside, Glasgow.
S.	1922.	McCleallan, C. J., 110, Carver Street, Sheffield.
Sc.	1925.	McCulloch, W., 174, Newlands Road, Cathcart, Glasgow.
M.	1927.	McCusker, C. B., 32, Lanehouse Road, Thornaby-on-Tees.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
M.	1927.	McCusker, M. S., 6, Wood Street, Stockton-on-Tees.
Lncs.	1924.	McDermott, J. P., 118, Briersill Avenue, Rochdale.
S.	1913.	Macdonald, W. A., 49, Nether Edge Road, Sheffield.
E.M.	1924.	McDonald, D. M., 45, Stenson Road, Derby.
Sc.	1913.	McDonald, W. F., 5, Hutchinson Place, Cambuslang.
Sc.	1917.	MacDougall, Miss E., 22, Clarendon Street, St. George's Cross, Glasgow.
Sc.	1911.	McEachen, J., Regent Street, Kirkintilloch.
B.	1904.	McFarlane, T., Farm Road, Horsehay, Salop.
Sc.	1920.	McGovan, A., 69, Battlefield Avenue, Langside, Glasgow.
Sc.	1910.	McGowan, R. R., Colliston-by-Arbroath.
Sc.	1927.	McIntyre, R., 102, Thistle Street, Camelon, Falkirk.
Sc.	1910.	Mackay, G., 103, Glasgow Road, Paisley.
Lncs.	1923.	McKenzie, Wm., c/o J. Hodgkinson, Ltd., Ford Lane Works, Pendleton, Manchester.
Sc.	1922.	McKinnon, J. C., Leaside Cottage, Cogan Street, Barrhead.
Sc.	1923.	McKinty, J. (Thompson & Lichtner Co.), 80, Federal Street, Boston, Mass, U.S.A.
Lncs.	1922.	Maclachlan, J. R., 7, Newall Mount, Otley, Yorks.
Sc.	1910.	McLachlan, W., 5, Dawson Terrace, Carron, Falkirk.
Sc.	1928.	McMahon, R., 10, Gilmour Street, Kilmarnock.
Sc.	1915.	McNab, J., Bells Wynd, Falkirk.
Sc.	1924.	McNab, R., 13, Walker Street, Paisley.
Sc.	1910.	McPhie, H., 40, Philip Street, Falkirk.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1927.	McGhie, D. C., 110, Grantly Gardens, Shawlands, Glasgow.
Lncs.	1927.	McVie, J., 507, Stretford Road, Old Trafford, Manchester.
Sc.	1926.	McWhirter, A., 49, Addison Drive, St. Giles, Lincoln.
Gen.	1925.	Mahindra, J. C., 6 and 7, Clive Street, Calcutta, India.
N.	1928.	Mallan, R., 7, Lowthian Terrace, Washington Station, Co. Durham.
Lncs.	1921.	Mallett, E., 1152, Chorley Old Road, Bolton.
B.	1909.	Marks, J., Sunbury House, 40, Titford Road, Langley, Birmingham.
Lncs.	1923.	Marlow, E., Brownoak, Western Road, Urmston, nr. Manchester.
Sc.	1910.	Marshall, G., "Fereneze," Russell Street, Burnbank, Lanarkshire.
L.	1922.	Marshall, H. C., 29, Westward Road, S. Chingford.
Sc.	1912.	Marshall, W. G., "Kyleakin," Larkhall, Scotland.
Lncs.	1925.	Marsland, J., 205, Manchester Road, Droylesden, Manchester.
Lncs.	1913.	Marsland, T., 401, Manchester Road, Droylesden, Manchester.
Gen.	1924.	Mason, A., 2, Lindsey Street, Frodingham, Scunthorpe, Lincs.
Lncs.	1927.	Martin, W., 34, St. George Street, Withington, Manchester.
B.	1925.	Massey, J. S., 49, Hawkes Lane, Hill Top, West Bromwich.
B.	1922.	Masters, T. J., 12, Glover Street, West Bromwich.
L.	1928.	Mathieson, J., 2, Duke's Road, East Ham, London, E.16.
B.	1921.	Mawby, R. A., Hopstone, Bridgnorth, Salop.
Lncs.	1926.	Mazarachi, A. C., 42, Ullet Road, Liverpool.
Lncs.	1925.	Meadowcroft, H., 14, Worcester Street, Rochdale.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1914.	Mearns, A., Bengal Iron Co., Kulti, E. I. R., India.
E.M.	1928.	Measures, J. F., 4, Paton Street, Leicester.
Sc.	1924.	Meikle, A. S., 207, Kent Road, Glasgow.
L.	1928.	Melling, J., 724 Liverpool Road, Peel Green, Patricroft.
Lncs.	1926.	Mellor, W., 166, West Street, Oldham.
Sc.	1928.	Melrose, W. J., 9, Stevenson Terrace, Bathgate.
M.	1926.	Menzies, A., 31, Cambridge Road, Thornaby-on-Tees.
Lncs.	1926.	Merigold, J. J., 67, Swans Lane, Bolton.
S.	1913.	Miller, A., 90, Bawtry Road, Tinsley, Sheffield.
Lncs.	1928.	Milner, H., 1, Abbotsford Road, Chorlton-cum-Hardy, Manchester.
W.R. of Y.	1923.	Milner, J. W., 29, Welbeck Street, Sandal, Wakefield.
Sc.	1928.	Mirrlees, R., 23, Fleming Street, Kilmarnock.
Sc.	1927.	Mitchell, W. C., 93, Glasgow Road, Paisley.
Sc.	1922.	Mitra, S. B., c/o Bengal Iron Co., Ltd., Kulti, E. I. R., India.
Lncs.	1918.	Moffat, J., 12, Dryden Street, Padiham, Lancs.
W.R. of Y.	1927.	Moffitt, R., 172, Devonshire Street, Keighley, Yorks.
Sc.	1916.	Moir, J. D., Bo'ness Iron Company, Ltd., Bo'ness, Scotland.
Sc.	1926.	Moir, T., 10, Alma Street, Falkirk, N.B.
B.	1916.	Mole, T., 7, Delville Road, Church Hill, Wednesbury.
E.M.	1921.	Moodie, Colin, 169, Station Road, Beeston, Notts.
B.	1928.	Moore, L. G., 77, Harden Road, Leamore, Walsall.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1926.	Moore, R. C., 61, Fitzwarren Street, Seedley, Manchester.
B.	1916.	Moore, W. H., Devonia, Moat Road, Langley Green, Birmingham.
N.	1920.	Moorhead, H. A., 22, Moorland Crescent, Walker Estate, Newcastle.
Sc.	1909.	Morehead, J. S., 98, Wilton Street, Kelvinside, Glasgow.
B.	1919.	Morewood, J. L., 23, Ravenshaw Road, Edgbaston, Birmingham.
B.	1926.	Morgan, E. S., Dalkeith, Stechford Lane, Ward End, Birmingham.
W. & M.	1922.	Morgan, W., Bryn Derwen, Bryn Terrace, Porth, Glam., So. Wales.
N.	1924.	Mudie, T., 34, Beech Grove, Monkseaton.
Sc.	1927.	Muir, W., 23, Wallace Street, Falkirk, Scotland.
N.	1913.	Murray, J., 5, Elmwood Avenue, Willington, Quay-on-Tyne.
Sc.	1927.	Murray, T., 36, McLelland Drive, Kilmarnock.
S.	1914.	Naylor, A., 239, Abbeyfield Road, Pitsmoor, Sheffield.
L.	1915.	Naylor, F., 7, Hume's Avenue, Hanwell, London, W.7.
B.	1926.	Neath, F. K., 24, St. Paul's Square, Birmingham.
Lncs.	1925.	Needham, G. A., 11, Newbridge Lane, Stockport.
W.R. of Y.	1925.	Neild, G., 3, Baden Terrace, Hough End, Bramley, Leeds.
N.	1914.	Nekervis, J., 14, Broughton Road, South Shields.
Gen.	1921.	Newland, J. E., 37, Provost Street, Holbeck, Leeds.
Lncs.	1912.	Nicholls, J., 146, Hulton Street, Trafford Road, Salford.
N.	1921.	Nicholson, J. D., 13, Taylor Street, South Shields.
Lncs.	1928.	Nield, T. A., 31, Highfield Road, Levenshulme, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1918.	Nisbet, H. L., Lilyburn, 91, Hillend Road, Lambhill, Glasgow.
Lncs.	1924.	Noble, J., 88, Reddish Lane, Gorton, Manchester.
Lncs.	1928.	Norton, L., 65, High Street, Dean Lane, Newton Heath, Manchester.
L.	1928.	Nunns, J. R., "Brunswick," 116, Mayplace Road, Bexley Heath, Kent.
S.	1921.	Offiler, G., 9, Ward Place, Highfields, Sheffield.
Lncs.	1920.	Oldham, R., 191, Dill Hall Lane, Church, Lancs.
Lncs.	1923.	Ollier, A. L., 53, Gorse Street, Stretford, Manchester.
N.	1910.	Olsen, W., Cogan Street, Hull.
Sc.	1920.	Orman, Wm., 55, Sunnyside Street, Camelon, Falkirk.
E.M.	1927.	Orme, R. F., "Hallworth," Hinchley Road, Leicester, Forest East.
E.M.	1928.	Oswin, H. A., 37, The Banks, Sileby, nr. Leicester.
B.	1922.	Owen, A. C., Gladstone House, Ketley Bank, near Wellington, Salop.
Lncs.	1924.	Owen, W., 33, Granville Road, Gorton, Manchester.
S.	1914.	Oxley, C., 101, Montgomery Road, Sheffield.
B.	1924.	Palmer, A., 14, Marsh Hill, Stockland Green, Birmingham.
Sc.	1928.	Parker, A. P., Williamlea, Morningside, Newmains.
B.	1925.	Parkes, I., 157, Whitehall Road, Greets Green, West Bromwich.
L.	1920.	Parnell, H., "Freda Villa," 25, Queen's Road, Burnham-on-Crouch.
Lncs.	1925.	Parrington, P., 30, Vernon Street, Bury.
B.	1926.	Parsons, D. J., Chawn Hill, Stourbridge.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1914.	Patrick, A., 65, Mungalhead Road, Falkirk.
B.	1925.	Patrick, J., 5, St. Margaret's Street, Canterbury, Victoria, Australia.
L.	1925.	Payton, T. G., 5, Victoria Street, Dunstable, Beds.
L.	1929.	Peacock, F. C., 52, Butt Road, Colchester.
B.	1929.	Pearce, F. C., 111, Earlsdon Avenue, Coventry.
E.M.	1928.	C. S. Pearn, Warnham, Gibson's Lane, Berstall, Leicester.
N.	1925.	Pearson, C. E., 2, Pearl Street, Saltburn-by-Sea.
E.M.	1927.	Pedge, F., 23, Foundry Cottages, Syston, nr. Leicester.
E.M.	1906.	Pemberton, H., 15, Wolfa Street, Derby.
E.M.	1929.	Perkins, F. H., 57, Darry House Road, Derby.
L.	1927.	Perry, A. E., 122, Tufnell Park Road, London, N.7.
L.	1928.	Pierce, W. E., 51, Headcorn Road, Bromley, Kent.
Lncs.	1922.	Phillips, A., 38, Gorse Crescent, Stretford, Manchester.
Sc.	1929.	Phillips, W., Viewfield Cottage, Wallacestone, Falkirk.
B.	1927.	Phillips, H., "Fairholme," Parkvale Avenue, Wednesbury, Staffs.
B.	1918.	Pickin, J., Lilac Cottage, Doseley, Dawley, Salop.
L.	1920.	Pierce, G. C., 11, Athelney Street, Bellingham, S.E.6.
S.	1928.	Pochin, G. D., 56, Joshua Road, Nether Edge, Sheffield.
S.	1926.	Pollard, C. D., 392, Firth Park Road, Sheffield.
Lncs.	1918.	Potts, W., 1, Far Lane, Hyde Road, Gorton, Manchester.
N.	1928.	Pratt, W., 23, Dene Street, Pallion, Sunderland.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1928.	Preston, G. W., 46, Edward Street, Nr. Openshaw, Manchester.
Lncs.	1929.	Preston, W., 46, Horbury Street, Elton, Bury.
Lncs.	1922.	Priestley, Jos., 258, Waterloo Street, Bolton, Lancs
Lncs.	1922.	Priestley, Thos., 185, Kay Street, Bolton, Lancs.
Sc.	1928.	Proctor, T. F., 2, Lorne Terrace, Maryhill, Glasgow, N.W.
B.	1909.	Pugh, C. B., Ramsay House, Besoot, Walsall.
S.	1917.	Pugsley, T. M., "Argyle," Morley Avenue, Rosebery, Sydney, N.S.W.
E.M.	1916.	Radford, H. P., 151, Barclay Street, Leicester.
M.	1929.	Rae, A., 79, Lanehouse Road, Thornaby-on-Tees.
Gen.	1928.	Ramaseshaih, Mysore Iron Works, Bhadrayati, India.
M.	1926.	Ramsey, J. E., 95, Princes Road, Middlesbrough.
M.	1926.	Rand, T., 11, Pearl Street, Saltburn-by-Sea.
Sc.	1904.	Rankin, R. L. (Sharp & Company), Lennox Foundry, Alexandria, Scotland.
Gen.	1928.	Rao, J. S. Gangadhar, Mysore Ironworks, Bhadrayati, S. India.
L.	1920.	Rasbridge, W. J., 160, Evelyn Street, Deptford, S.E.
Lncs.	1910.	Rawlinson, W., "Fairhaven," Portland Road, Ellesmere Park, Eccles, Manchester.
W. & M.	1928.	Rea, H., 176, Caerleon Road, Newport.
N.	1928.	Reece, P., 120, Northbourne Street, Gateshead.
Lncs.	1927.	Reynolds, J. A., "Nirvana," Eccleston Park, near Prescot.
Lncs.	1907.	Reynolds, W., 13, Park View Terrace, Oldham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R.	1922.	Rhodes, W., 20, Hope View, Carr Lane, Windhill, Yorks.
S.	1922.	Rhodes, Wm., Beech Holme, Ecclesfield, nr. Sheffield.
W. & M.	1928.	Richards, T. D., 23, Keppoch Street, Cardiff.
L.	1925.	Richards, W. S., 68, Beatrice Avenue, Keyham Barton, Devonport.
Lncs.	1929.	Richardson, J., 38, Willows Lane, Accrington.
N.	1912.	Richardson, W., 204, South Frederick Street, South Shields.
L.	1924.	Richman, A. J., "Strathaven," Brooks Hall Road, Ipswich.
Lncs.	1927.	Ridyard, A., 26, Astonwood Road, Higher Tranmere, Birkenhead.
Lncs.	1911.	Riley, J., M.Sc., A.M.I.C.E., A.M.I. Mech.E., M.I. & S.I., 3, Glen Road, off Lees Road, Oldham.
Lncs.	1927.	Rishton, H. A., 78, Fern Bank, Haslingden, Rossendale.
S.	1912.	Roberts, G. E., 149, Sharrow Vale Road, Sheffield.
N.	1921.	Robertson, H., 60, Ryhope Road, Grangetown, Sunderland.
Sc.	1920.	Robinson, C. H., West Dene, Lochairnvoich Road, Kilmacolin, Scotland.
Lncs.	1920.	Robinson, F., 369, Wigan Road, Deane, Bolton.
B.	1929.	Robinson, H. W., 296, Walsall Road, Fallings Heath, Wednesbury.
B.	1925.	Robinson, J., 8, Esplanade East, Calcutta, India.
M.	1917.	Robinson, J. H., c/o. R. W. Crosthwaite, Ltd., Union Foundry, Thornaby-on-Tees.
Lncs.	1928.	Robinson, S. E., 39, Hood Street, Accrington.
L.	1927.	Robson, N. E., 10, Railway Street, Braintree, Essex.
N.	1919.	Robson, F., 44, Stannington Place, Heaton, Newcastle-on-Tyne.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W. & M.	1928.	Rogers, D., 3, Coronation Road, Llanelly, S. Wales.
S.	1913.	Rodgers, F., Brightside Foundry & Engineering Co., Ltd., Newhall Iron Works, Sheffield.
S.	1913.	Rodgers, J. R. R., 362, Firth Park Road, Sheffield.
Sc.	1924.	Rodgers, P., Jubilee Place, Bonnybridge.
B.	1917.	Roe, H. J., 29, Park Road, Moseley, Birmingham.
Gen.	1920.	Rogers, C. F., 28, Maycock Road, Coventry.
Sc.	1926.	Rolland, W., 10, Victoria Drive, Scotstoun, Glasgow.
Sc.	1922.	Ross, E. J., 12, Afton Street, Langside, Glasgow.
Lncs.	1922.	Rowe, F. W., 41, Moorside Avenue, Crosland Moor, Huddersfield.
E.M.	1924.	Rowell, E. L., 30, Russell Street, Nottingham.
W.R. of Y.	1922.	Rowntree, F., 9, St. Mary's Road, Bradford, Yorks.
S.	1927.	Roxburgh, J., 720, Abbeydale Road, Sheffield.
E.M.	1928.	Rushton, D., 93, Violet Street, Derby.
Sc.	1928.	Russell, M., 29, Laurel Street, Partick.
M.	1926.	Rutherford, C., "Inglefield," Eaglescliffe, near Yarm., S.O.
N.	1925.	Rutledge, W. B., 61, North View, Heaton, Newcastle-on-Tyne.
Lncs.	1924.	Ryding, F., 52, Barnsley Street, Wigan, Lancs.
W.R. of Y.	1927.	Rymer, A. S., West Bank, Heworth, York.
L.	1923.	Sanders, H. H., 21, Etherley Road, Harringay, N.15.
E.M.	1921.	Sanders, Horace L., 61, Rowditch Avenue, Derby.
B.	1905.	Sands, J., 27, Victoria Street, West Bromwich.
M.	1926.	Sault, A., 23, Collin's Avenue, Norton-on-Tees.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1928.	Saunders, R. A. D., 24, St. Paul's Road, Hemel Hempstead, Herts.
Lncs.	1928.	Schofield, H., B.Sc., 37, Birch Hall Lane, Longsight, Manchester.
S.	1927.	Scholes, A., 35, Bromwich Road, Woodseats, Sheffield.
Sc.	1928.	Scott, A., Wallace Street, Falkirk.
Sc.	1923.	Scott, C., 1426, 8th Street, Apt. of Rockford, Illinois, U.S.A.
N.	1916.	Scott, G. W., 1, Northumberland Villas, Wallsend-on-Tyne.
N.	1918.	Scott, W., 7, Lynwood Avenue, Blaydon-on-Tyne.
M.	1926.	Seaman, A., 1, Cowper Bewley Road, Haverton Hill, Middlesbrough.
S.	1921.	Senior, George, 305, Upperthorpe, Sheffield.
Lncs.	1925.	Service, J., 78, Highfield Road, Seedley, Manchester.
W. & M.	1929.	Seymour, L. W., Bucklebury Alley, Cold Ash, nr. Newbury, Berks.
W.R. of Y.	1913.	Shackleton, H. R., Upper Pear Tree Farm, Hainsworth Shay, Keighley.
Sc.	1928.	Shaw, J., 91½, Kirk Road, Wishaw.
L.	1924.	Shawyer, G. H., 81, Edward Street, Deptford, S.E.8.
L.	1926.	Shawyer, junr., G. W., 81, Edward Street, Deptford, S.E.8.
B.	1924.	Shearman, F. E., 63, Summerfield Crescent, Edgbaston, Birmingham.
Lncs.	1926.	Shepherd, F. L., 215, Tottington Road, Bury.
S.	1929.	Sheppard, H., 164, Hasland Road, Hasland.
S.	1923.	Sherratt, W., 39, Horndean Road, Pitsmoor, Sheffield.
E.M.	1925.	Sherriff, C., 12, Central Road, Loughborough.
B.	1925.	Shore, A. J., "Bradda," Quinton Hill, Birmingham.
B.	1920.	Shorthouse, W. H., Haybridge Ironworks, Wellington, Salop.

B'nch.	Year of Election.	ASSOCIATE MEMBERS
B.	1927.	Shwalbe, O., 62, Milverton Road, Erdington, Birmingham.
Lncs.	1922.	Simkiss, H., 28, Energy Street, Bradford Road, Manchester.
B.	1914.	Simpson, H., Greenhurst, Doseley, Dawley, Salop.
W.R. of Y.	1925.	Simpson, J. A., 3, Jesmond Place, Hunslet Hall Road, Leeds.
N.	1916.	Sinclair, J., 25, Granville Street, Millfield, Sunderland.
Lncs.	1905.	Skelton, H. S., "Lindsey," Old Lane, Eccleston Park, Prescot, Lancs.
S.	1925.	Skerl, J. G. A., M.Sc., Dept. of Applied Science, St. George's Square, Sheffield.
L.	1925.	Skidmore, B., 2, Jackmans Place, Letchworth, Herts.
E.M.	1925.	Slade, R. H., 254, St. Thomas Road, Derby.
L.	1911.	Slater, H. O., "Sunny Hill," Lessners Park, Belvedere, Kent.
W.R. of Y.	1928.	Slingsby, T. J. L., Highfield Villa, Keighley, Yorks.
Lncs.	1906.	Smethurst, J. H., Briery Croft, Lodge Lane, Warrington.
L.	1927.	Smith, A. C., 9, Greenway Gardens, London, N.W.3.
E.M.	1928.	Smith, A. E. W., 152, St. Thomas' Road, Derby.
Sc.	1927.	Smith, B. D., 27, Corsewall Street, Coatbridge.
E.M.	1928.	Smith, C. H., 467, Osmaston Park Road, Derby.
Lncs.	1925.	Smith, F., 15, Milnrow Road, Rochdale.
Sc.	1921.	Smith, J., 6, Kennard Street, Falkirk.
B.	1917.	Smith, S., 114, Tetley Road, Hall Green, Birmingham.
Lncs.	1909.	Smith, S. G., 121, Davyhulme Road, Stretford, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1924.	Smith, W., 358, Halifax Road, Todmorden.
Lncs.	1929.	Smith, W., 11, Springs Road, Kitt Green, nr. Wigan.
E.M.	1925.	Smith, W. F., 152, St. Thomas Road, Derby.
B.	1928.	Smith, W. F., 148, Willow Avenue, Edgbaston, Birmingham.
E.M.	1926.	Smith, W. H., Ryton Grange Avenue, Normanton, Derby.
W.R. of Y.	1924.	Smith, Wm., Main Road, Kesgrave, Ipswich.
M.	1929.	Smithson, John K., South Avenue, Stillington New Middlesborough.
N.	1929.	Snaith, G. T., 78, Nora Street, High Barnes, Sunderland.
Sc.	1924.	Sneddon, F. M., 28, Forest Street, Mile End, Glasgow.
S.	1924.	Somerfield, H., 146, Sandygate Road, Sheffield.
W. & M.	1928.	Southcott, S., Wood View, Ynysymaerdy, Briton Ferry, S. Wales.
N.	1929.	Spedding, G. H., 3, Railway Street, Tow Law, Co. Durham.
Sc.	1920.	Spittal, J., 82, Norham Street, Shawlands, Glasgow.
Lncs.	1926.	Stacey, C. W., 19, Derbyshire Crescent, Stretford, Manchester.
B.	1927.	Stanton, L., 8, Low-wood Road, Erdington, Birmingham.
Sc.	1918.	Stark, W. C.,
B.	1917.	Starr, F. G. 128, Selwyn Road, Rotton Park, Birmingham.
Lncs.	1917.	Stead, H., 1st 36, Cheetham Hill Road, Stalybridge.
S.	1914.	Steggles, A. L., 240, Bellhouse Road, Sheffield.
B.	1914.	Stephen, S. W. B., The Woodlands, Hagley Road West, Birmingham.
L.	1921.	Stevens, Wm., "Newland," Church Road, Rodbourne, Cheney, Swindon.
Sc.	1925.	Stirling, E., York Place, Kirkintilloch.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
N.	1914.	Stobbs, R., 199, Stanhope Road, South Shields.
W. & M.	1929.	Stokes, W., 18, Moira Street, Cardiff.
Lncs.	1920.	Storer, W. H., 255, Settle Street, Great Lever, Bolton.
W.R. of Y.	1926.	Stott, E., 4, Orchard Street, Otley, Yorks.
Sc.	1928.	Stewart, G. G., Smiths' Buildings, Bridgend, Bathgate.
L.	1925.	Stubbs, R. G., 290, Commercial Road, Peckham, S.E.15.
L.	1922.	Summers, H. G., 35, Perry Hill, Catford, S.E.6.
E.M.	1927.	Summersgill, E. (Junior), 47, Station Road, Long Eaton, Notts.
Lncs.	1910.	Sutcliffe, A., 1, Firwood Grove, Tonge Moor, Bolton.
Lncs.	1919.	Sutcliffe, W., 3, Birkdale Road, Turf Hill, Rochdale.
Lncs.	1923.	Swann, H., 31, Alexandra Road, Patricroft, Manchester.
Sc.	1927.	Syme, T. R., 307, Murray Place, off Bilsland Drive, Glasgow, N.W.
Lncs.	1922.	Tate, C. M., Brook Royd, Todmorden Road, Burnley.
Gen.	1906.	Taylor, A. (Fielding & Platt, Limited), Atlas Ironworks, Gloucester.
M.	1926.	Taylor, D., 35, Langley Avenue, Thornaby-on-Tees.
B.	1925.	Taylor, E. R., 148, South Road, Handsworth, Birmingham.
W. & M.	1905.	Taylor, F. J., J.P. (Taylor & Sons, Limited), Briton Ferry, South Wales.
B.	1926.	Taylor, F., J.P., "The Willows," Gipsy Lane, Willenhall, Staffs.
Lncs.	1921.	Taylor, James, 3, Tremellen Street, Accrington.
S.	1926.	Taylor, R. J. S., Hill Crest, Broomhall Lane, Old Whittington, Chesterfield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R. of Y.	1927.	Taylor, W., 77, Dorchester Road, North Shore, Blackpool.
L.	1925.	Teasdale, I., Homeland, Norton Village, Letchworth.
N.	1921.	Temple, G. T., 35, Grosvenor Drive, Whitley Bay.
B.	1926.	Tennant, A. McA., 57, Bramford Lane, Erdington, Birmingham.
Lncs.	1922.	Thatcher, E. H., The Newport Foundry Co., Mill Parade, Newport.
N.	1924.	Thom, J., 11, Moorland Crescent, Walker, Newcastle-on-Tyne.
L.	1909.	Thomas, E., 41, Kingshill Road, Swindon.
Lncs.	1929.	Thompson, J., 4, Picking Street, Chester Road, Manchester.
L.	1926.	Thompson, J. S., "Arley," Bedonwell Hill, Abbey Wood, S.E.2.
Sc.	1925.	Thomson, D. B., 1 Knowe Terrace, Hillend Road, Lambhill, Glasgow.
S.	1921.	Thomson, T. R.,
E.M.	1929.	Thornton, A., Derby Road, Hathern, nr. Loughborough.
S.	1923.	Thornton, A. E., 34, Hampton Road, Pitsmoor, Sheffield.
L.	1927.	Tichelly, L. J., Universal System of Machine Moulding Ltd., 13/15, Wilson Street, London, E.C.2.
Lncs.	1911.	Timmins, A. E., 133, Roose Road, Barrow-in-Furness.
Lncs.	1924.	Timperley, T., 30, Ventnor Road, Heaton Moor, Stockport.
E.M.	1928.	Tompkin, A., 54, Havelock Street, Leicester.
E.M.	1927.	Tompkin, S. E., 332, East Park Road, Leicester.
Sc.	1925.	Tonagh, Chas., 254, Stevenson Street, Calton, Glasgow.
Lncs.	1914.	Topping, G., 17, Bebbington Street, Clayton, Manchester.
Sc.	1920.	Trapp, P., Kilnside Cottage, Falkirk.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
E.M.	1924.	Tunnicliffe, F. J., 9, Augusta Street, Derby.
Sc.	1923.	Turnbull, Alex. W., Primrose Cottage, Bonnybridge.
W.R. of Y.	1927.	Turner, L., 14, Whitwell Green, Dewsbury Road, Elland
S.	1918.	Turner, W., 90, Edgedale Road, Sheffield.
B.	1923.	Twigger, T. R., Post Office, Bubbenhall, nr. Kenilworth.
Sc.	1927.	Tyrie, T., 35, Melville Street, Kilmarnock.
L.	1925.	Underwood, W. G., 5, Farlton Road, Earlsfield, S.W.18.
Sc.	1920.	Ure, R., Stenhouse House, Carron, Falkirk.
N.	1922.	Van-Der-Ben, C. R., 169, Dunsmuir Grove, Gateshead.
E.M.	1928.	Varney, F., 18, Sale Street, Derby.
E.M.	1921.	Vaughan, Benj. H., 25, Holmes Street, Derby.
B.	1917.	Vaughan, G. A., Pen Glen, Tividale Road, Burnt Tree, Tipton.
Lncs.	1921.	Vernon, G. W., 11, Ashfield Road, Burnley.
E.M.	1928.	Waby, W., 11, Northwood Street, Stapleford, Notts.
M.	1928.	Waddell, 30, Mills Street, Newport, Middlesbrough.
N.	1914.	Wainford, E. H., 17, Windsor Road, Saltburn-by-the-Sea.
Lncs.	1925.	Walker, A., 117, Robert Street, Newton Heath, Manchester.
Lncs.	1928.	Walker, A., 45, Highfield Road, Levenshulme, Manchester.
B.	1928.	Walker, A., "Coogee," Lower Hillmorton Road, Rugby.
Lncs.	1921.	Walker, Alex. W., 113, Dalton Green Lane, Huddersfield.
Sc.	1920.	Walker, D., 5, New Houses, Anderson Street, Bonnybridge.
L.	1922.	Walker, F. D., 153, Greenvale Road, Eltham, S.E.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1920.	Walker, G., 21, Napier Place, Bainsford, Falkirk.
E.M.	1920.	Walker, Geo. H., 2, Camp Street, Derby.
Sc.	1920.	Walker, Wm., 10, Larbert Road, Bonnybridge, Falkirk.
W. & M.	1929.	Wall, A., 6, Denton Road, Canton, Cardiff.
B.	1916.	Wall, J., 15, Flavell Street, Woodsetton, nr. Dudley.
S.	1927.	Walmsley, T., 2, Calder Way, Firth Park, Sheffield.
Lncs.	1915.	Wallwork, R. N., Western Road, Wilmslow, Cheshire.
E.M.	1924.	Ward, J. C., Wilnouth, Collingham Road, Leicester.
E.M.	1925.	Warner, Amos, 252, St. Thomas Road, Derby.
Lncs.	1928.	Warner, H. E., 128, Rosemeath Road, Urmston, nr. Manchester.
S.	1928.	Wass, E., 1, Oliver Road, Balby, Doncaster.
S.	1911.	Wasteney, J., Vulcan Foundry, Eckington, nr. Chesterfield.
Gen.	1914.	Watson, R., Saxilley House, 49, York Street, Rugby.
Sc.	1919.	Watt, R., Etna Ironworks, Falkirk.
L.	1927.	Watts, W., 23, Rolt Street, Deptford, London, S.E.8.
W. & M.	1928.	Wayman, M., 12, Foxcote Road, Bedminster, Bristol.
B.	1923.	Webb, A. W. J., 1, Sidney Street, Gloucester.
B.	1927.	Webb, A. E., 45, Brettell Street, Dudley, Worcester.
E.M.	1921.	Webb, Ernest Alfred, Bettwyscoed, Hinckley Road, Kirby Muxlo, near Leicester.
S.	1909.	Webster, C., 34, Milton Road, Rotherham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1927.	Webster, D. M., 15, Garden Terrace, Falkirk.
Sc.	1928.	Webster, J. F., 4, Carnegie Street, Arbroath, Scotland.
B.	1926.	Webster, W., 74, Horseley Road, Tipton, Staffs.
W. & M.	1928.	West, S. J., 44, Hungerford Road, Weston, Bath.
B.	1911.	Westwood, J. H., 1583, Stratford Road, Hall Green, Birmingham.
Lncs.	1925.	Wharton, L., 4, Ridehalgh Street, Colne, Lancs.
W.R. of Y.	1913.	Whitaker, E., 164, Cliffe Wood. Mount, Shipley.
Lncs.	1928.	Whitaker, G., 43, Naples Avenue, Stoops Farm, Estate, Burnley.
W.R. of Y.	1928.	Whitaker, G. H., 20, Sandy Wood Street, Keighley.
W.R. of Y.	1928.	Whitaker, S., 164, Cliffe Wood Mount, Shipley.
M.	1926.	Whitfield, C. S., Bengal Ironworks, Kulti, E.I.R., Bengal, India.
L.	1911.	Whiting, A., Brynhella, Pembroke Road, Erith, Kent.
L.	1924.	Whiting, A. F., East View, Field Lane, Letchworth, Herts.
Lncs.	1929.	Whitton, A., 96, Monk Street, Accrington.
E.M.	1928.	Whysall, J., 75, Snecton Boulevard, Nottingham.
E.M.	1928.	Whysall, John, 22, Mafeking Street, Nottingham.
S.	1925.	Wild, A. J., Midland Brass Foundry, Attercliffe, Sheffield.
E.M.	1926.	Wild, H., 14, Albert Promenade, Loughborough, Leicestershire.
M.	1926.	Wilkes, R., 39, Pearl Street, Haverton Hill, Middlesbrough.
M.	1910.	Wilkinson, T., Stockton Street, Middlesbrough.
S.	1919.	Williams, A., 31, Burngreave Bank, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1925.	Williams, O., 25, Thirlmere Avenue, Stretford, Manchester.
L.	1927.	Williams, S. V., 22, Mayfield Avenue, Kenton, Middlesex.
Sc.	1911.	Williamson, H., 3, Nairn Street, Dalmuir.
Sc.	1920.	Williamson, J., 111, Stirling Street, Denny, Stirlingshire.
L.	1920.	Willsher, W. H., "Breydon," Oakhill Gardens, Woodford Green, London, E.18.
Lncs.	1919.	Wilson, A. E., 84, Dewhurst Road, Syke, Rochdale.
L.	1925.	Wilson, A. M., Messrs. Parlanti, Beaumont Road, W. Kensington.
L.	1927.	Wilson, C. H. V., 31, King's Avenue, Clapham Park, London, S.W.4.
Sc.	1927.	Wilson, J., 30, Polworth Gardens, Edinburgh.
Lncs.	1928.	Wilson, J. E., 15, Kaye Lane, Almondbury, Huddersfield.
Sc.	1928.	Wilson, J., 43, West Thornlie Street, Wishaw.
Sc.	1927.	Wilson, J. R., 2, Lindon Place, Anniesland, Glasgow.
B.	1929.	Wilson, R., 6, Cobden Street, Wednesbury, Staffs.
Sc.	1928.	Wilson, W. M., 105, Arkleston Road, Paisley.
Lncs.	1904.	Wilson, W. R., 15, Sackville Street, Liverpool.
E.M.	1921.	Winfield, F., "Ambleside," Osmaston Park Road, Derby.
W.R. of Y.	1926.	Winter, N.F.S., Green Hayes, Halifax.
E.M.	1928.	Winterton, W. L., 195, Berridge Road, Nottingham.
W.R. of Y.	1924.	Wise, S. F., 110, Pullan Avenue, Eccleshill, Bradford.
Lncs.	1912.	Wolstenholme, J., 111, Carlton Terrace, Bury, and Bolton Road, Radcliffe, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1922.	Wood, A., 30, Toll End Road, Tipton, Staffs.
B.	1927.	Wood, A., Sunny Bank Hill, Crest Avenue, Brierley Hill.
S.	1926.	Wood, E. A., 30, Dixon Street, Rotherham.
W.R. of Y.	1922.	Wood, John, 6, Hudswell Street, Sandal, Wakefield.
B.	1927.	Woolen, R., 19, Gillott Road, Edgbaston, Birmingham.
M.	1926.	Woolley, R. E., 5, Albion Terrace, Saltburn-by-Sea.
B.	1927.	Worley, S. C., "Ashmore," 153, Bearwood Road, Smethwick, Birmingham.
W. & M.	1926.	Wren, J., "Westholm," Edward Street, Griffithstown, Mon.
Lncs.	1925.	Wright, H. G., 78, Lloyd Street, Heaton Norris, Stockport.
W.R. of Y.	1923.	Wright, L. L., 168, Oxford Road, Gomersall, near Leeds.
B.	1927.	Wright, R. E., Oxford Lodge, Penn Fields, Wolverhampton.
Sc.	1913.	Wright, W., Burnbank Foundry, Falkirk.
Lncs.	1924.	Wylie, J. F., 206, Stockport Road, Bredbury, Stockport.
Lncs.	1925.	Yates, J., 8, Bury Road, St. Stephen's Estate, Bury.
Lncs.	1928.	Yates, S., Hayfield Road, Chapel-en-le-Frith.
Lncs.	1926.	Yates, W., 38, Clifford Street, Leigh, Lancashire.
Lncs.	1924.	Yeoman, Robert, 49, Wellington Road North, Stockport.
Lncs.	1926.	Yeoman, S., 42, Wellington Road North, Stockport.
Sc.	1919.	Young, J., 45, Cochrane Street, Paisley.
N.	1921.	Young, James, 72, Carlisle Street, Felling-on-Tyne.

ASSOCIATES.

B'nch.	Year of Election.	
N.	1925.	Adams, F., 98, Avondale Road, Byker, Newcastle.
B.	1925.	Andrews, E., 56, Lansdown Road, West Didsbury.
B.	1925.	Bache, T. R., 181, Walsall Street, West Bromwich.
N.	1925.	Badsey, R. C., 5, Lovaine Terrace, North Shields.
N.	1920.	Banks, V. L., St. Cuthbert's Vicarage, Newcastle-on-Tyne.
N.	1929.	Barrett, J. H., 27, Fairless Street, South Shields.
Sc.	1927.	Bell, W. M., 2, Bellfield Street, Barrhead.
N.	1924.	Betham, W. S., 4, Dixon Street, South Shields.
N.	1929.	Birks, E., 36, King Edward Street, Gateshead-on-Tyne.
N.	1925.	Blackwell, J., 131, George Street, Willington-Quay-on-Tyne.
Sc.	1926.	Blackwood, W. S., 12, Napier Street, Linwood, Scotland.
Sc.	1927.	Blythe, N. C., 11, Danes Drive, Scotstoun, Glasgow.
B.	1922.	Boudry, C., 46, Holly Lane, Smethwick.
N.	1929.	Bowie, S., 1, North Grove, Roker.
B.	1914.	Boyne, W., 158, Moor End Lane, Erdington, Birmingham.
N.	1928.	Buchan, S., 100, Quadrant, Balkwell, North Shields.
N.	1928.	Buckley, B. A., 3, Monk Street, Sunderland.
L.	1928.	Burgess, F. G., 13, Saxon Road, Luton, Beds.
M.	1926.	Cannon, W. R., 9, South View, Billingham, Stockton-on-Tees.
L.	1928.	Challis, R. L., 29, Tower Hamlets Road, Forest Gate, London, E.7.
L.	1924.	Chamberlain, E. E., 70, Albert Street, Slough, Bucks.

B'nch.	Year of Election.	ASSOCIATES.
Sc.	1926.	Clark, J., 28, King Street, Paisley.
W. & M.	1925.	Coles, H.,
Lncs.	1927.	Connell, C. H., 9, Muriel Street, Great Clowes Street, Lr. Broughton.
N.	1929.	Cook, W., 7, Smith Street, Tow Law, Co. Durham.
N.	1928.	Cosgrove, J., 295, Stanhope Road, South Shields.
Sc.	1925.	Coubrough, W. J., 68, Guthrie Street, Maryhill, Glasgow.
N.	1928.	Cox, S., 78, Stanley Street, Rosehill, Willington-on-Tyne.
N.	1928.	Crowe, T. E., 3, Westbourne Road, Sunderland.
L.	1926.	Cummings, F. C., 3, Waller Road, New Cross, London, S.E.16.
Gen.	1918.	Currie, E. M., 3, Stockton Road, Coventry.
N.	1924.	Cuthbertson, J., 81, Dunsmuir Grove, Gateshead-on-Tyne.
Lncs.	1927.	Daintith, R., 286, Rishton Lane, Gt. Lever, Bolton.
S.	1927.	Dalton, W. E., 310, Owler Lane, Sheffield.
N.	1924.	Davidson, T. H., 24, Langley Street, Newcastle.
N.	1923.	Davison, R., 79, Second Avenue, Heaton, Newcastle-on-Tyne.
B.	1928.	Dawkins, B. J., "Rosemary," Lansdowne Avenue, Bakem, Wolverhampton.
N.	1924.	Dickinson, B., 9, South Frederick Street, South Shields.
N.	1924.	Dodd, C., 6, Relton Terrace, Monkseaton.
L.	1928.	Doulton, M. D., Windmill House, Clapham Common, London, S.W.4.
B.	1925.	Dubberley, W., 27, Lewisham Road, Smethwick, Birmingham.
N.	1926.	Dunbar, J., 16, Burn Terrace, Willington Quay-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
N.	1918.	Eglen, T., 521, Chillingham Road High Heaton, Newcastle-on-Tyne
N.	1918.	Elsdon, W., 7, Berwick Terrace Percy Main.
N.	1918.	Errington, R., 12, Fern Dene Road, Gateshead.
B.	1925.	Evans, E. H., 100, Brunswick Road, Handsworth, Birmingham.
Sc.	1927.	Ewen, G., 29, Oakbank Terrace, Glasgow.
N.	1917.	Ferguson, J., 62, South Palmerston Street, South Shields.
S.	1922.	Firth, Tom L.. 191, Fox St., Sheffield.
N.	1925.	Fleck, J., 75, Lamb Street, Walker-on-Tyne.
N.	1913.	Ford, A., 43, Moore Street, Gateshead.
B.	1929.	Fox, A., "Beechmont," Birmingham Road, Walsall.
S.	1926.	Fretwell, J., 153, Sheffield Road, Stonegravels, Chesterfield.
B.	1924.	Frost, C., 55, Waverley Road, Small Heath, Birmingham.
N.	1928.	Gibson, A. A., 131, Bewicke Road, Willington Quay on Tyne,
N.	1929.	Gibson, C. S., 3, Winifred Gardens, Wallsend-on-Tyne.
N.	1929.	Gibson, E., 13, Potter Street, Willington Quay.
N.	1929.	Gibson, T. W., 2, Dukes Cottages, Newburn-on-Tyne.
Sc.	1924.	Graham, T., 25, William Street, Dumbarton.
Sc.	1928.	Graham, W., 94, Waverley Drive, Wishaw.
L.	1924.	Greaves, J. H., 38, Solway Road, Wood Green, N.22.
N.	1925.	Green, S., 25, Campbell Street, Newcastle-on-Tyne.
B.	1925.	Greenway, J. F., 43, Douglas Road, Handsworth, Birmingham.
N.	1925.	Grigor, R., 38, Grey Street, Wallsend-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
B.	1925.	Hadley, E. T., 207, Horseley Heath, Tipton, Staffs.
N.	1929.	Hall, J. W., 86, Eighth Avenue, Heaton, Newcastle-on-Tyne.
B.	1909.	Hamilton, G., 13, Anderson Road, Tipton.
W. & M.	1925.	Harding, W. L., 14, Welford Street, Barry.
N.	1923.	Harle, J. E., 162, South Palmerston Street, South Shields.
M.	1926.	Harvey, E. J., 4, Rydal Road, Stockton-on-Tees.
Sc.	1927.	Harvie, R., 21, Campbell Street, Maryhill, Glasgow.
S.	1921.	Heeley, John Jas., 36, Gertrude Street, Owlerton, Sheffield.
Sc.	1924.	Higgins, N., 7, Portland Rows, Hurlford, Ayrshire.
Sc.	1920.	Hill, T., 146, Kippen Street, Airdrie.
Lncs.	1925.	Hindley, W., 13, Charles Street, Farnworth, near Bolton.
B.	1926.	Hird, J., 165, Showell Green Lane, Sparkhill, Birmingham.
N.	1925.	Hodgkinson, H. D., 1, Rose Avenue, Whickam, Gateshead.
E.M.	1917.	Holmes, A,, 87, Albert Promenade, Loughborough.
Lncs.	1923.	Hopkins, W., 70, Tootal Drive, Weaste, Manchester.
N.	1928.	Howse, R., 1, Jersey Street, West Hartlepool.
N.	1927.	Hunter, R. W., 104, Shrewsbury Crescent, Humbledon Hill, Sunderland.
N.	1928.	Jagger, E., 28, Franklin Street, Jarrow.
M.	1926.	Jameson, J. R., 9, Olive Street, Hartlepool.
Sc.	1927.	Jardine, W., 98, Bank Street, Alexandria, Dumbartonshire.
N.	1929.	Jennings, R., 139, Weldon Crescent, Heaton, Newcastle-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
B.	1919.	Johnson, J. B., junr., Slater Street, Great Bridge, Tipton.
W. & M.	1928.	Jones, C. E., 65, Cathedral Road, Cardiff.
N.	1925.	Jones, J., 21, Cooper Street, Sunderland Road, Gateshead-on-Tyne.
N.	1928.	Kirkland, J., 28, Camden Street, North Shields.
N.	1922.	Kelly, F. J., 1545, Walker Road, Newcastle-on-Tyne.
L.	1929.	Kent, B. B., Fire Pines, Longdon Wood, Keston, Kent.
S.	1928.	Kenyon, P., 75, Queen Street, New Brimington, Chesterfield.
Sc.	1928.	Laird, T., 3a, Buccleuch Terrace, Cambusnethian, Wishaw.
N.	1928.	Lamberton, J., 19, Railway Street, Jarrow-on-Tyne.
Sc.	1924.	Laughland, H., 15, Burnside Street, Kilmarnock.
S.	1928.	Law, H. O., 43, Carlisle Road, Grimesthorpe, Sheffield.
N.	1928.	Lowes, E. G., 10, Sunningdale Avenue, Walker-on-Tyne.
N.	1924.	Lowes, W., 1, Baden Street, Chester-le-Street.
Lncs.	1914.	Lucas, G. W., 36, Langford Street, Leek, Staffs.
N.	1929.	McDonald, C. R., The Villa, Willington, Quay-on-Tyne.
N.	1925.	McDougal, T. D., 3, Westmoreland Street, Wallsend-on-Tyne.
N.	—	McErlane, H., 64, St. James' Square, Gateshead.
Sc.	1924.	McGowan, V. M., 1, Albert Street, Paisley.
Sc.	1926.	McGurnaghan, M., 206, Gallowgate, Glasgow.
Sc.	1913.	McLeish, J., 7, Buchanan Terrace, Paisley.
N.	1926.	McQuillan, J., 1, Lodge Terrace, Wallsend-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
Sc.	1927.	Main, J. W., 175, Holm Street, Glasgow, C.2.
N.	1929.	Mark, T., 46, Hedley Street, Gosforth, Newcastle-on-Tyne.
Sc.	1924.	Martin, A. L., 31, George Street, City, Glasgow.
M.	1926.	Martin, J. H., 29, Marton Grove Road, Middlesbrough.
L.	1925.	Mata, C. H., 51, Grosvenor Road, Canonbury, N.5.
Lncs.	1923.	Meadowcroft, H., 10, Hambledon, View, Habergham, Burnley.
B.	1925.	Meredith, C., 4, Thomas Street, Smethwick, Birmingham.
N.	1929.	Miller, G. S., Foundry House, Seaham Harbour.
N.	1928.	Mitchinson, T. S., Bank Top House, Walbottle, Newburn-on-Tyne.
N.	1929.	Moat, A. M., 38, Victoria Avenue, Wallsend-on-Tyne.
S.	1925.	Nesbit, G. L., 7, Ruskin Avenue, Mexborough.
N.	1925.	Nesbitt, J., 26, Bede Crescent, Holy Cross Estate, Willington-Quay-on-Tyne.
N.	1924.	Nichol, J., 131, George Street, Willington-Quay-on-Tyne.
N.	1929.	Nixon, E., 56, Wolsley Gardens, Newcastle.
N.	1929.	Noble, E., 135, Ayton Street, Byker, Newcastle.
N.	1925.	Nuttall, G., 88, High Street East, Wallsend-on-Tyne.
N.	1925.	Osborne, G. F., 39, Franklin Street, Sunderland.
S.	1929.	Oxley, T. A., Tapton Heights, Tapton Ville Road, Sheffield.
N.	1923.	Peacock, J. E., 40, Bolam Street, Newcastle-on-Tyne.
N.	1923.	Peacock, S., 12, John Street, South Shields.
N.	1922.	Picken, A. D., 87, Cuthbert Street, Hebburn-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
N.	1928.	Pillow, H. C., 3, Delaval Road, Whitley Bay.
L.	1922.	Pittuck, M. D. (Miss), c/o H. J. Young. 3, Central Buildings, Westminster. S.W.1.
Lncs.	1926.	Pollard, Wm., 104, Rose Hill Road, Burnley, Lancs.
N.	1926.	Pratt, S., 29, Randolph Street, Jarrow-on-Tyne.
N.	1917.	Rang, E. J., M.Sc., 8, Bath Terrace, Tynemouth.
N.	1926.	Reay, T., 27, Percy Street, Wallsend-on-Tyne.
N.	1922.	Redpath, J., 25, Burnley Street, Blaydon-on-Tyne.
N.	—	Reece, T. E., 120, Northbourne Street, Gateshead.
W. & M.	1925.	Rees, L. W.,
Sc.	1927.	Reid, A., 12, Anderson Street, Burnbank, Hamilton.
Sc.	1923.	Reid, J. N. (junr.), Elmbank, Larbert.
S.	1929.	Rhodes, W., 80, Skimmerthorpe Road, Firvale, Sheffield.
Sc.	1923.	Riddell, J., 113, Coventry Drive, Glasgow.
M.	1926.	Robinson, J., 172, Abingdon Road, Middlesbrough.
N.	1924.	Robson, J., 15, Hawthorne Grove, Wallsend-on-Tyne.
N.	1925.	Robson, J., 20, Frederick Street, Gateshead-on-Tyne.
N.	1928.	Robson, R. W., 6, Nelson Street, Gateshead.
N.	1923.	Rollin, C. N., Stanhope House, Westoe Village, South Shields.
Sc.	1927.	Rose, D., 12, Victoria Street, Alexandria, Dumbartonshire.
Sc.	1927.	Ross, W. (Junior), 2, Macdonald Street, Rutherglen, Glasgow.
N.	1926.	Rowley, J. S., 51, South Terrace, Wallsend-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
N.	1925.	Ruff, J., 88, Richardson Street, Wallsend-on-Tyne.
M.	1926.	Saunders, A., 34, Queens Road, North Ormesby, Middlesbrough.
N.	1928.	Savage, T., 56, Hastings Street, Hendon, Sunderland.
N.	1925.	Scott, R. J., 32, North Terrace, Wallsend.
L	1926.	Sherman, W. T., "Woodlands," Avery Hill Road, New Eltham.
N.	1929.	Slassor, J. B., 243, Sunderland Road, Gateshead.
S.	1925.	Smedley, C. C., 41, Abbey Lane, Woodseats, Sheffield.
B.	1925.	Smith, W. H., 21, Horseley Road, Tipton, Staffs.
N.	1925.	Soulsby, W. A., 14, Armstrong Terrace, Gosforth Newcastle.
		South, G. E., 13, Struan Road, Carterknowle, Sheffield.
N.	1912.	Spence, W. D., 124, Heaton Park Road, Newcastle-on-Tyne.
N.	1922.	Spencer, F. C., "Dunsfell," New Horseley, Ovingham-on-Tyne.
B.	1910.	Spiers, F., 4, Angel Street, Worcester.
N.	1925.	Spowart, D., 31, Houghton Avenue, Cullercoats.
N.	1926.	Stafford, J., 143, Harriet Street, Byker, Newcastle-on-Tyne.
Lncs.	1927.	Stanworth, S., The Woodlands, Rimington, Clitheroe.
N.	1928.	Steele, D., 4, Boundary Street, Willington Quay.
N.	1924.	Stoddart, J., 7, Ferndale Avenue, Wallsend-on-Tyne.
N.	1925.	Strong, Leslie, 59, Marine Avenue, Monkseaton, Northumberland.
E.M.	1915.	Styles, W. T., 52, Roe Street, Derby.
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